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February 28, 2013

Ms. Demaree Collier
U.S. Environmental Protection Agency
Region 5 (HSRM-6J)
77 West Jackson Blvd.
Chicago, IL 60604

Subject: Monitored Natural Attenuation Study Workplan – Revision 2
Lemberger Landfill Sites
Town of Franklin, Wisconsin

Dear Ms. Collier:

Please find attached one copy of the above-referenced document. Revision 1 of this Workplan was submitted in November 2012. In order to expedite the field effort, USEPA approved the well installation portion of the Workplan via email dated November 6, 2012, so that the well installations could be completed before the winter. The monitoring wells were installed in November/December 2012. Section 2 of the enclosed document describes the proposed well installations, and we did not feel it was appropriate to modify the text of this section so the tense of the text in Section 2 remains in the future tense.

Please review and approve the enclosed document. If you have any questions, please contact me (608-826-3637) or Brian Potts (608-258-4772).

Sincerely,

TRC Environmental Corporation

Kristopher D. Krause, P.E.
Senior Project Manager

Enclosure

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Mr. Chris Meyer – The Manitowoc Company, Inc.
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Monitored Natural Attenuation Study Workplan for the LTR Near-Field Area

**Lemberger Transport and Recycling Site
Groundwater Operable Unit OU-1
Town of Franklin, Manitowoc County, Wisconsin**

EPA ID #WID056247208

**February 2013
Revision 2**

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Section 1

Introduction

1.1 Background

The Lemberger Sites Remediation Group (LSRG) has implemented the United States Environmental Protection Agency's (USEPA) selected remedial action for restoring contaminated groundwater in the vicinity of the Lemberger Landfill (LL) and the Lemberger Transport and Recycling (LTR) sites (Lemberger sites), which are located near Whitelaw, Manitowoc County, Wisconsin. Past disposal practices at the LTR site resulted in a plume of chlorinated volatile organic compounds (CVOCs) including trichloroethylene (TCE) and 1,1,1-trichloroethane (1,1,1-TCA). It is well documented that under the proper conditions these common groundwater contaminants degrade in the environment through biologically-mediated reductive dechlorination (e.g., Weidemeier et al., 1995; USEPA, 1998). USEPA has recognized that these microbial processes may constitute a viable remedial action, commonly referred to as monitored natural attenuation (MNA).

An MNA study is proposed in this workplan to evaluate MNA as a remedial option for addressing the CVOC plume (the plume). A previous MNA study was conducted in 2006 to 2008. This earlier study had objectives related to the ROD-specified cleanup goals equivalent to the WDNR PAL concentrations and compliance at the waste boundary. The objectives of that study as described in the Workplan (RMT, 2006) were as follows:

- To determine whether existing natural attenuation processes will maintain the current acceptable level of protectiveness of human health and the environment at the site, as predicted by the completed groundwater modeling simulations of future VOC plume conditions;
- To confirm that the existing pump-and-treat system provides only limited effectiveness in capturing the VOC plume;
- To perform a full-scale site demonstration to identify the chemical, biological, and physical processes that are providing the natural attenuation of VOCs in the groundwater plume;
- To determine the relative effectiveness of the natural attenuation processes over the extent of the contaminated groundwater areas;
- To obtain data to evaluate natural attenuation at the site in accordance with current guidance documents prepared by USEPA and WDNR, as well as with the large volume of technical literature available on this subject; and

- To gather the information necessary to provide the technical basis to support a change of the groundwater remedial action from the current use of pump-and-treat technology, to the use of monitored natural attenuation, as appropriate.

Groundwater samples were collected from over 50 monitoring wells over a two-year period for the study (RMT, 2008). The results of the MNA study indicated that biodegradation of the parent compounds (PCE, TCE, and 1,1,1-TCA) is occurring and concentrations of CVOCs are decreasing. The study confirmed that natural biodegradation was responsible for the decreasing trends of CVOCs rather than groundwater extraction. USEPA (2010) agreed that biodegradation was occurring at the LTR source, but was limited elsewhere due to low levels of organic carbon and high concentrations of dissolved oxygen.

In 2012, USEPA and the Wisconsin Department of Natural Resources (WDNR) noted that the time for the LSRG to achieve cleanup standards may be shortened if the point of standards application for each of the Lemberger sites was changed to a design management zone (DMZ) as allowed by Wisconsin Administrative Code (WAC) Chapter NR 140.22 (3) rather than the limit of the waste, as it is currently defined. The agencies also indicated that the Record of Decision (ROD)-specified cleanup criteria for the CVOCs could be revised to the WDNR Enforcement Standard (ES), which is equivalent to USEPA drinking water standards, rather than the current Preventive Action Limit (PAL). When it became apparent that making these changes would still result in an area of groundwater between the LTR and LL being impacted above the ES, a second MNA study was suggested that would focus on outside the DMZs for the LL and LTR, in particular between the former landfills and ES-based cleanup goals. This study will provide the basis for deciding whether an MNA remedy, ES-based cleanup goals, and DMZ-defined compliance boundaries would provide an acceptable modification/alternative to the current ROD specifications. This area, in the immediate vicinity of the LL and LTR, has been referred to as the “near-field” area in documents as early as the Remedial Investigation (B&V, 1991). The near field area is illustrated on Figure 1. Subsequent conversations with the agencies concluded that the second MNA demonstration would benefit from the addition of bedrock monitoring wells to fill data gaps in the near-field area and at depth along the plume.

1.2 Workplan Objective and Scope

The objective of this MNA Workplan (Workplan) is to:

- Document the technical details for additional monitoring well installations;
- Document the technical details of the MNA data collection and interpretation activities;
- Present a schedule for the activities, including submission of deliverables.

1.3 Site Conceptual Model as it Relates to MNA

In order to assess the treatment system's performance, a conceptual model for the fate and transport of constituents of concern from the LTR was presented (RMT, 2004) to the USEPA and WDNR. USEPA (2010) also provided a review and summary of the conceptual model. The following describes an overview of the conceptual model with a focus on the area near the LTR.

1.3.1 Site Location and Topography

The Lemberger sites are located on the west side of Hempton Lake Road approximately two miles north of Whitelaw, Wisconsin and two miles southeast of the community of Taus. The site is in an area of rural farms and single family homes in gently rolling terrain. There are many small wetlands between the hills and several have no outlet and form shallow ponds. Ridgeview Landfill (owned by Waste Management of Illinois, Inc.) is located approximately one-half mile northeast of the LTR. There is an abandoned limestone quarry located less than 1,000 feet southwest of the LTR.

Elevations in the area range from 940 feet (National Geodetic Vertical Datum of 1929 [NGVD]) on several hilltops, to 790 feet on the Branch River at the East Taus Road bridge (Figure 1). The Lemberger sites are at an elevation of approximately 840 feet NGVD with the topography sloping west towards the river. Ditches drain the LTR site and convey runoff to a wooded wetland north of Sunny Slope Road. That wetland is drained by a ditch that conveys water west to an unnamed tributary to the Branch River. Another ditch conveys water from wetlands west of the LL south-southwest to the same tributary. The Branch River flows north in the vicinity of the sites then meanders south to join the Manitowoc River approximately 3 miles southwest of Whitelaw.

1.3.2 Hydrogeology

The hydrogeologic setting at the Lemberger sites is comprised of an unconsolidated and bedrock aquifer. The granular aquifer and underlying sediments are of glacial origin. The sediments are heterogeneous and consists of an upper, unconfined perched aquifer system called the upper granular unit (UGU) or upper groundwater system (UGS), a confining unit (CU; where present) of clayey glacial till, and a lower granular unit of sand and gravel (LGU) that overlies the bedrock. The LGU and bedrock are hydrologically connected and collectively known as the lower groundwater system (LGS) (USEPA, 2010).

The glacial sequence generally thins to the east and is completely absent at some locations immediately west of the LTR, and at some areas along Hempton Lake Road, giving way to exposed dolomitic limestone bedrock. The bedrock surface exposed

immediately west of the LTR is characteristically smooth from glaciation, but in the subsurface is weathered, with solutionally enlarged fractures and bedding surfaces. Observations from rock coring reveal that weathering decreases with depth, resulting in a more isotropic lithology. The rock fabric is also highly variable, ranging from highly porous, fossiliferous limestone to dolomitized lime mudstone with very low porosity and low permeability.

At the LTR, the UGU (where present) is unsaturated, and the CU is often found directly overlying the shallow bedrock. The UGU thickens to the north, however, and is saturated within 1,500 feet north of the LTR site. Along the north LTR boundary, the LGU is present only in an unsaturated bedrock trough in the vicinity of the RM-7 well nest. That trough may extend to the northwest as far as RM-3D. Wells proposed in this Workplan will better delineate the extent of this feature. The bedrock is unsaturated to a depth of approximately 40 feet (approximately 815 feet NGVD) beneath the LTR.

1.3.3 Groundwater

The potentiometric surface resides in the bedrock approximately 40 feet below ground surface at the LTR. Groundwater in the LGS flows north and west away from the LTR towards the Branch River. The groundwater flow direction in the LGS has remained consistently to the north-northwest throughout the 16 years of monitoring. No significant changes in flow direction occur seasonally, despite the fact that water levels typically fluctuate several feet throughout the year. Vertical gradients are rather weak in the bedrock aquifer and can vary both upwards and downwards, even at a given well nest. At the RM-7 well nest, gradients are more consistently downward.

1.3.4 Groundwater Analytical Data Summary

The key groundwater constituents of the contaminant plume are CVOCs. Specific CVOCs have been used to depict the extent of the plume, most notably TCE and its breakdown products [e.g., cis-1,2-dichloroethene (cis-1,2-DCE) and vinyl chloride] and 1,1,1-TCA and its breakdown products [e.g., 1,1-dichloroethane (1,1-DCA) and chloroethane]. The distribution of TCE is typically displayed to show the extent of the LTR contaminant plume, primarily because TCE has a lower ES (5 µg/L) than 1,1,1-TCA (200 µg/L) and is almost as widely distributed within the plume.

The current plume extends over one mile from the LTR. Historical data and interpretations indicate the general plume configuration has not changed, and concentrations of these key parent compounds have decreased or remained stable in most LGS wells. In general, the plume “does not appear to be expanding” (USEPA, 2010), when its limits are defined by the PAL (i.e., 0.5 µg/L). If the plume limits are defined by extent of ES exceedences of TCE (i.e., 5 µg/L), the plume extent has contracted substantially. ES exceedences of TCE were routinely reported as distant as EW-4I and RM-210D in the first 10 years of monitoring. Those wells are located approximately 5,000 feet north of the current edge of the plume, as defined by the ES for TCE (5 µg/L). CVOCs that exceed the ES are currently between 1,500 and 2,000 feet north and west of the LTR boundary. With seasonal fluctuations, the plume extent can decrease to less than 800 feet from the north edge of the LTR (often referred to as “the toe of the LTR”).

Monitoring and drilling data indicate that the plume extends to an elevation between 730 and 650 feet NGVD (approximately 110 to 190 feet bgs). The 80 feet of uncertainty in the actual vertical extent of contamination is identified as a data gap and serves as justification for the installation of the additional monitoring wells proposed in this Workplan. CVOC concentrations in wells near the top of rock are often lower than the concentrations found in nearby deeper wells. The concentrations are nowhere near those that would suggest dense non-aqueous phase liquids (DNAPL) (i.e., 1% of the TCE saturation limit of 11,000 µg/L; Pankow and Cherry, 1996).

1.4 Proposed Revisions to the Remedial Action Objectives

The LSRG proposes to revise the Remedial Action Objectives (RAO) for groundwater at the Lemberger site. The proposed revised RAOs are:

- To restore groundwater quality over time to achieve, to the extent practicable, groundwater quality standards that are equivalent to the WDNR ES.
- Revise the point of compliance to a maximum of 450 feet from the limits of waste in the LTR and LL in accordance with NR 140.22 (3). The proposed limits are illustrated by the DMZs in Figure 1.

The LSRG believes that the remedial objectives selected in the ROD (USEPA, 1990) can be achieved through continued natural attenuation of the CVOCs (RMT, 2008) and maintenance of the existing cap system. As determined in the 2010 USEPA Five Year Review, the Lemberger sites do not pose a current threat to human health or to the environment. The current monitoring system and institutional controls restrict exposures and protect human health and the environment. The additional monitoring wells proposed in this workplan will provide

monitoring at the revised boundaries. As a result, the proposed revision of the RAOs is consistent with, and will achieve, the ROD's goal of protecting human health and the environment.

1.5 Previous MNA Study

In previous planning for an MNA engineering demonstration study for the plume, RMT concluded that the plume was "stable and fully protective of human health and the environment" (RMT, 2004). The study concluded that the primary evidence of biologically mediated reductive dechlorination was the presence of breakdown products such as cis-1,2-DCE at the source area. Other evidence included lower concentrations of dissolved oxygen and nitrate, and higher concentrations of inorganic carbon and carbon dioxide in the source area wells. However, the data for several other constituents were inconsistent with regulatory guidance values that would indicate MNA is occurring. Outside of the source area, the groundwater is generally more aerobic, with some exceptions at individual wells.

In the 5-year review, USEPA (2010) agreed that the site remedies at the Lemberger sites (i.e., site covers, fencing, institutional controls, regular groundwater sampling) are currently protective. Their review also commented that the geochemical data collected in the 2008 MNA study were often contradictory and did not show clear relationships as presented in guidance and similar publications. USEPA concluded that microbial activity actively degrades TCE and 1,1,1-TCA in (and below) the LTR, but bioactivity diminishes immediately downgradient as water becomes oxygenated. Using the terminology outlined in Parsons (2004) and originally proposed by Weidemeier, et al. (1995), USEPA (2010) characterized the biotic environment within the LTR as Type 1 (highly anaerobic and conducive to bioactivity), reverting rapidly at the LTR boundary to Type 3 (aerobic and not conducive to bioactivity), with isolated intervening areas of Type 2 (mildly conducive to bioactivity). This mixed type of environment can result in a buildup of cis-1,2-DCE and the probable rapid oxidation of vinyl chloride directly to carbon dioxide (Parsons, 2004). The cis-1,2-DCE will also slowly degrade aerobically as is seen throughout the plume.

1.6 USEPA MNA Protocol

USEPA's Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water (USEPA, 1998) defines the key steps for evaluating natural attenuation, as listed below. Several of these steps have already been completed for the Lemberger sites.

Step 1: Develop a preliminary conceptual model of contaminant sources and behavior at the site. **Completed – RMT, 2004**

- Step 2:** Apply screening process (defined in the guidance) to assess the potential for natural attenuation. **Completed – USEPA, 2010. Will be reassessed as part of this study.**
- Step 3:** If the screening process suggests that natural attenuation is potentially appropriate, perform additional site characterization to further evaluate natural attenuation. **Additional site characterization and monitoring are proposed in this Workplan.**
- Step 4:** Refine the conceptual model based on site data, and make pre-modeling calculations of contaminant behavior. **Included in scope of this study.**
- Step 5:** Simulate natural attenuation effects using a solute fate-and-transport model. **The existing transport model was found to be inappropriate in this setting by the LSRG and USEPA. Therefore, simpler analytical models will be used.**
- Step 6:** Complete a receptor exposure pathways analysis. **Institutional controls are in place that are protective of receptors.**
- Step 7:** Evaluate the need for supplemental source control measures. **Will be evaluated, as appropriate.**
- Step 8:** Prepare a long-term monitoring plan. **Environmental Monitoring Plan that addresses long-term monitoring is in preparation.**
- Step 9:** Present the findings of the natural attenuation evaluation. **Included in scope of this study.**

USEPA guidance documents (USEPA, 2004a) also suggest the following representative techniques for demonstrating the effectiveness of MNA, with respect to the remedial objectives identified for a site:

1. Demonstrate that natural attenuation is occurring according to expectations.
2. Detect changes in environmental conditions (e.g., hydrogeologic, geochemical, microbiological, or other changes) that may reduce the efficacy of the natural attenuation processes.
3. Identify any potentially toxic and/or mobile transformation products.
4. Verify that the plume(s) is not expanding downgradient, laterally, or vertically.
5. Verify no unacceptable impact to downgradient receptors.
6. Detect new releases of contaminants to the environment that could impact the effectiveness of the natural attenuation remedy.

7. Demonstrate the efficacy of institutional controls that were put in place to protect potential receptors.
8. Verify attainment of remediation objectives.

The proposed MNA demonstration project described in this Workplan follows the steps in the MNA demonstration protocol noted above, and will provide the data needed for USEPA to assess the effectiveness of MNA based on the objectives listed above.

1.7 Lines of Evidence

USEPA has identified the following three lines of evidence that can be used to estimate natural attenuation of chlorinated VOCs (USEPA, 1999):

1. Historical groundwater and/or soil chemistry data that demonstrate a clear and meaningful trend of decreasing contaminant mass and/or concentration over time at appropriate monitoring or sampling points.
2. Hydrogeologic and geochemical data that can be used to demonstrate **indirectly** [original emphasis] the type(s) of natural attenuation processes active at the site, and the rate at which such processes will reduce contaminant concentrations to required levels.
3. Data from field or microcosm studies (conducted in or with actual contaminated site media) which **directly** [original emphasis] demonstrate the occurrence of a particular natural attenuation process at the site and its ability to degrade the contaminants of concern (typically used to demonstrate biological degradation processes only).

USEPA (1999) provides the following guidance on expectations for demonstrating these lines of evidence:

"Unless EPA or the overseeing regulatory authority determines that historical data (#1 above) are of sufficient quality and duration to support a decision to use MNA, data characterizing the nature and rates of natural attenuation processes at the site (#2 above) should be provided. Where the latter are also inadequate or inconclusive, data from microcosm studies (#3 above) may also be necessary."

The MNA demonstration project described in this Workplan is designed to provide the data necessary to evaluate MNA according to all three lines of evidence defined by USEPA. Sampling and testing to follow the third line of evidence (laboratory microbiological or microcosm testing) was not conducted in the previous MNA study because it was not expected to yield worthwhile or conclusive results due to difficulties associated with attempting to apply such techniques to groundwater contamination in fractured rock conditions. While these

conditions have not changed, microbiological testing will be performed because results of the previous MNA study were mixed, and these data could assist in the evaluation.

Section 2

Field Activities

The purpose of the field effort is to:

1. Install additional monitoring wells in the “near-field” area and downgradient of the LL to monitor the plume to fill monitoring data gaps, and
2. Collect geochemical and microbiological data to evaluate the viability of MNA.

These data will be used to confirm whether MNA is capable of remediating the plume in a reasonable timeframe.

2.1 Field Activities

This section outlines the methods and procedures that will be performed to implement the MNA study. The LSRG will begin implementation of the well installation following approval of the Workplan and after obtaining the necessary property rights.

2.1.1 Selection of Contractors

TRC will prepare and execute subcontracts to complete the MNA study. TRC has selected a qualified drilling contractor to drill and install the monitoring wells. Boart Longyear of Schofield, Wisconsin (Boart) was selected based on qualifications, prior site experience, and cost. Pace Analytical Laboratories of Green Bay, Wisconsin (Pace) will continue to perform as the laboratory subcontractor for chemical analyses. A specialized laboratory—Microbial Insights, Inc. (Microbial Insights) of Rockford, TN—will supply samplers and analyze the samples for beneficial microbes. A local surveyor with prior site experience will be selected to survey the well locations. TRC will also subcontract a local heavy equipment operator to clear the trees and construct the access to the RM-402XD/-XXD location.

2.1.2 Monitoring Well Siting and Site Improvements

The scope of work includes the installation of seven new monitoring wells at the approximate locations shown on Figure 1. TRC will notify the affected landowners prior to finalizing the plans to drill. Boart will obtain the necessary utility clearances. TRC field staff will review site features and access, and will stake each of the well locations illustrated on Figure 1 prior to mobilization of the drilling equipment. The well locations may be moved based on conditions observed in the field considering access with the drill rig and the intent of the data to be collected from the well. The well

locations will be placed as close as practicable to coordinates entered (from the locations on Figure 1) into a hand-held Trimble® Global Positioning System (GPS) capable of sub-meter accuracy. Final drilling locations will be staked and painted on the ground to ensure the holes are drilled at their proper locations. Each location will then be surveyed by a registered land surveyor to obtain the local ground surface elevation. Elevation control is critical to the proper placement of the well screens.

Access to at least one of the well nest locations (RM-402XD/XXD) will require construction of a temporary limited use road to allow access for the drilling rig. The road will remain after drilling to allow access to the wells using an all-terrain vehicle. The proposed road is currently planned to enter from the east side of the wooded area (Figure 1). A construction firm will remove the trees and stumps, then clear and grub the roadway, and place coarse aggregate as required to stabilize the roadbed. The RM-402XD/XXD well site may also be periodically inundated with surface water requiring the placement of soil or aggregate to keep the well out of standing water. The preferred method, however, will be to move the location to place it in a drier setting. If necessary, a berm will be constructed around the well nest to keep out surface water. Other well locations may require light grading and placement of aggregate on an as needed basis.

2.1.3 Drilling

Wells will be drilled using rotary sonic methods. This method entails using a rubber tired or track mounted drill rig capable of drilling to a minimum of 200 feet below ground surface (bgs). The hole is drilled by rotating a circular drill bit equipped with carbide steel and industrial diamonds. The oscillating drive head also imparts sonic energy to rapidly vibrate the head to penetrate harder materials. Sonic methods require a small quantity of potable water as the drilling fluid to cool the drill bit. Sonic methods typically result in 80 percent less investigative derived waste than mud rotary methods.

A sampling tube is fitted inside the drill string that continuously collects soil/rock samples while drilling for physical description. The sample tubes vary in length from 5 to 20 feet, and sample quality is typically very good to excellent, for most materials. The sample tube is the same for both soil and rock. Samples are extruded from the tube and into a sheath of plastic that is tied off at the bottom. The plastic sheath is labeled for depth by the driller and laid out for the TRC geologist for logging. The TRC geologist will ensure the depth communicated by the driller is correct and record the information on the field boring log. Sample cores will be photographed with appropriate labels of

depth, scale, color, etc. Photographs of core from each boring will be distributed to the appropriate project team members and included in the MNA report.

The area to be drilled will be covered with plastic sheeting and the driller will slope the plastic to contain drilling fluids. The fluids and finer solids will be periodically collected from the plastic and placed in 55-gallon drums. The fluids and solids will be handled as specified in Section 7.

At a minimum, the rear one-third of the drilling rig, all downhole equipment, and any equipment that comes in contact with contaminated downhole materials will be decontaminated prior to use on-site, and between borings, by using a pressurized cleaner. Decontamination must remove all visible downhole material to the satisfaction of the TRC On Site Coordinator (OSC). The rig will be placed over plastic during decontamination to contain fluids. Decontamination fluids will be contained and disposed as presented in Section 7.

2.1.4 Monitoring Well Installation

The proposed monitoring well screen depths are provided in Table 1. Figures 2 and 3 are cross-sections that show the relationship of the proposed monitoring wells to other wells and the subsurface materials. The screen depths have been established based on conversations between LSRG, USEPA, and WDNR. The screens for the wells proposed in this Workplan are placed to monitor what is presumed to be the center of the plume at depth. Monitoring these intervals is important for the MNA study as the three dimensional aspect of the plume should be clearly defined (Weidemeier et al., 1995; WDNR, 2003). The proposed screen elevations of the intermediate and deeper piezometers can be changed at the discretion of the field geologist up to 10 feet vertically in order to intersect any potential zone of interest (e.g., fractured or highly porous interval) based on observations made during drilling. Any such changes in the screen position will be discussed in advance with appropriate regulatory agency representatives prior to being implemented.

The monitoring wells will be named to be consistent with the current monitoring network, i.e., RM-402XD/-402XXD. These "400" series wells are so named because this effort is the fourth round of monitoring well installations. The wells will be constructed in accordance with the standards of WAC Chapter 141, and as summarized below:

- Borings for the wells will be drilled using rotary sonic drilling methods.
- Core samples will be visually described and logged by the TRC on-site geologist. The geologist will work closely with the drilling subcontractor to identify zones of

fracturing or higher relative porosity, as may be indicated by “bit drop,” reports of soft intervals, or intervals with lost drilling returns. Such observations will be recorded on the field logs. Samples from at least one complete boring (likely the deepest boring – RM-402 XXD) will be archived on site for future reference. An example of a boring log is provided in Appendix A.

- Figure 4 illustrates a typical well installation. The monitoring wells will be constructed with flush-threaded, 2-inch inside diameter (I.D.) Schedule 80 (or Schedule 40 for wells less than 100 feet total depth) polyvinyl chloride (PVC) riser and screen. Well screens will be constructed of 2-inch PVC with machine slotted 0.010-inch slots. Well materials will remain in clean plastic and/or their original packaging prior to installation. Drillers will wear clean surgical gloves when handling well materials.
- The PVC riser will extend to at least 2.5 feet above the ground surface. A small notch will be placed at the top of the PVC to serve as a measuring point for water level measurements.
- A filter pack consisting of 20-40 mesh clean, quartz sand will be placed between the well bore and the screen. The filter pack will extend to at least 2 feet above the well screen. A minimum of 2 feet of clean, fine sand will be placed above the filter pack.
- Each well will be sealed with at least 2 feet of bentonite chips or pellets (3/8-inch diameter). After allowing the bentonite seal to hydrate for at least 30 minutes, a cement-bentonite slurry will be placed above the bentonite seal in the annular space. Bentonite pellets or granules cannot be used as the annular space seal because the amount of standing water in the well will exceed 30 feet (see NR 141.13 (2) 3.b). The sealant will consist of a slurry of cement and high solids bentonite at the ratio of no less than 5 pounds of bentonite powder to 94 pounds of Portland cement and 8.5 gallons of clean water in accordance with NR 141.05 (8). The annular space seal shall be terminated 5 feet below ground surface (bgs).
- The PVC well will be protected with a steel cover pipe that extends to 5 feet bgs. Surface completions will consist of bentonite chips or granules that extend from 5 feet bgs to approximately 0.1 feet bgs. Natural soil will then be placed over the exposed bentonite and sloped to drain away from the completed well.
- Upon completion of the monitoring well installation the TRC geologist will prepare a monitoring well completion log that summarizes the well installation. An example of the log is provided in Appendix A.
- Three guard posts will be placed around the new wells at locations where vehicular traffic or farm equipment could damage the well. The guard posts will consist of nominal 4-inch steel pipe driven to a depth of 3 feet bgs and extending three feet above the ground surface. The posts will also be filled with concrete. At well nests, some guard posts may be shared, as practicable.

- The outside of the protective casing and guard posts will be painted bright yellow to match the existing site monitoring wells.
- After the well seal has been allowed to set and stabilize a minimum of 48 hours, each well will be developed by surging and pumping in accordance with NR141.21. Wells will be surged and purged for approximately 30 minutes; and then purged until ten (10) borehole volumes of water are removed or until the well produces sediment free water. The TRC geologist will prepare a well development log for each well (see example log in Appendix A).
- Boring logs, well completion forms, and development logs will be completed for each new monitoring well. These forms will be entered into a common geologic logging software program (gINT®) for clarity and consistency of presentation. The logs will be provided to the WDNR and USEPA within 90 days of installation. Each well will be assigned a unique Wisconsin well identifier and labeled in accordance with NR 141.23 (2).
- Assuming this plan is approved by EPA prior to October 30, 2012 and that the LSRG can obtain the necessary property rights prior to the proposed November well installation, the first round of groundwater sampling for the MNA demonstration project will be scheduled for March 2013, coincident with the scheduled interim groundwater monitoring event for the first quarter of 2013. In the event that the new wells are constructed prior to the scheduled fourth quarter 2012 interim groundwater monitoring event (December 2012), the new wells may be sampled during that event. Groundwater samples collected during 2012 will be analyzed for VOCs only to assess whether the well installation intersected the plume.

2.1.5 Surveying

A Wisconsin-registered land surveyor will survey each well and the adjacent ground surface after the wells have been installed. The base of the notch placed on the PVC riser and the top of ground immediately below that point will be surveyed to NAD83 (Datum) State Plane, Wisconsin – South Zone coordinates in U.S. feet, with a horizontal accuracy of +/- 0.1 foot and a vertical accuracy of +/- 0.01 foot. Vertical datum will be referenced to the National Geodetic Vertical Datum (NGVD) of 1929.

2.1.6 Well Installation Report

Within 60 days of the approval of this document, a technical memorandum will be submitted to the USEPA summarizing the well installations. The report will include boring logs, well completion forms, and development forms. Analytical results of initial VOC sampling of the new wells will be included. The report will also include new and revised cross sections that include the new wells. This evaluation may be important in

the interpretation of the MNA study, particularly if continuous fractures or fracture zones are identified that appear to influence the shape of the plume.

Section 3

MNA Groundwater Sampling

This section describes the equipment to be used and the general procedures to be followed for collecting groundwater samples associated with this MNA demonstration project. These procedures are consistent with the USEPA-approved Quality Assurance Project Plan (QAPP) (TRC, 2011b) and the Sampling and Analysis Plan (TRC, 2013 in prep).

The groundwater sampling protocol is designed to obtain samples that are representative of aquifer conditions. Data quality objectives for the MNA study will be prepared as part of a revision to applicable sections of the QAPP (TRC, 2011b). Valid and reliable results depend on the following:

- Obtaining representative samples
- Using proper sample collection, handling, and preservation techniques
- Identifying the collected samples and documenting their collection in permanent field records
- Maintaining sample Chain-of-Custody procedures
- Protecting the collected samples by properly packing and transporting them to the USEPA-approved laboratory for analysis

The procedures presented in this Workplan will be followed and any deviations from the specified procedures will be documented in the bound field notebooks.

3.1 General Considerations

The following factors and procedures are general considerations to be used in planning and performing groundwater sampling. These factors and procedures will be considered with respect to the specific objectives and scope of the field investigation, as presented in this Workplan and the QAPP:

- Safety of sampling personnel
- Selection and proper preparation of sampling equipment
- Selection of parameters to be measured and evaluation of sample fractions to be analyzed (e.g., dissolved, suspended, or total fractions for water samples)
- Required sample volumes
- Selection and proper preparation of sample containers
- Sample preservation

- Sample holding times
- Sample handling
- Sample identification
- Collection of auxiliary data
- Sample Chain-of-Custody
- Transportation and shipping of samples

3.2 Monitoring Well Sampling

Sampling from the monitoring wells will be completed using a low-flow pumping technique. This sampling method involves purging the well with the pump intake set at the desired sampling depth, and purging at a rate that should not mobilize naturally nonmobile colloidal matter, that does not create excessive water level drawdown, that minimizes pressure changes in the purged water, and that does not appreciably change the redox state of the sample. This sampling method minimizes the disturbance of the sample, thereby reducing sampling artifacts, and improves the consistency and quality of the groundwater sample results. In addition, the low-flow sampling method significantly reduces the volume of potentially contaminated purge water generated during the sampling process. In general, low-flow purging and sampling methods developed by USEPA (Appendix B) will be followed.

Each monitoring well will be pumped using a low flow sampling pump (portable bladder pump or similar). The pump intake will be placed approximately 1 to 2 feet above the bottom of the well screen and the well will be pumped at a target flow rate ranging from 0.2 to 0.5 liter/minute. The pumping rate for each monitoring well is dependent on the hydraulic properties of the formation the well is screened across, and will be determined in the field to be the highest flow rate attainable without creating drawdown greater than approximately 0.1 meter, or at a minimum rate of 200 mL/minute. In the event that the aquifer transmissivity is too low to yield sufficient water to limit drawdown to 0.1 meter at the lowest specified pumping rate (200 mL/minute), sampling will be conducted at the 200 mL/minute rate since this is the minimum flow rate necessary for accurate measurements through the flow-through cell, and to prevent water from freezing in the discharge lines during the winter months.

Field parameter measurements will be used to document stabilized conditions, and to indicate that sufficient purging has been performed (as described in Subsection 5.1). In the event that stabilization of the indicator parameters is not achieved in a reasonable amount of time (2 hours), but the water level is stable, the well may be sampled after four well screen volumes of water have been removed. If a well cannot sustain a pumping rate of 200 mL/minute, and can be purged dry at that rate (before four well screen volumes are removed), the well will be

purged dry and allowed to recover prior to sampling but for not more than 24 hours after purging. Well purging and stabilization data will be recorded on the Water Sample Log (Appendix A).

Following stabilization or water level recovery, samples for laboratory analysis will be collected into the appropriately labeled containers and placed on ice. The sample pump will be removed and decontaminated (see Subsection 4.2) and the tubing will be disposed following each sampling location and event.

Groundwater pumped during purging, tubing, and other general waste materials generated by the sampling will be collected and managed as investigation-derived waste materials as described in Section 7.

3.3 Groundwater Analytical Program for MNA Demonstration

Groundwater samples will be collected and analyzed from each of 23 monitoring wells on a quarterly basis, for at least four successive quarterly monitoring events in accordance with the MNA project schedule (Section 11). The groundwater samples will be collected and analyzed for the parameters indicated in Table 2. The locations of the wells included in the MNA demonstration program are shown on Figure 5. The new wells will be sampled in conjunction with the fourth quarter groundwater monitoring event in December 2012 and analyzed for VOCs only. The data from the December 2012 monitoring event will be the first sampling for the new wells and the data will be evaluated prior to the first MNA sampling event (March 2013). The new wells will be sampled quarterly for VOCs for a period of two years.

In addition to the analytical program summarized in Table 2, microbial samples will be collected following the June 2013 sample event from eight wells in the near source area (RM-7D, RM-7XD, RM-209D, RM-303D, RM-306D, RM-307D, RM-402XD, and RM-403XD). These samples will be analyzed for microbial DNA for *Dehalococcoides* spp. (for breakdown of TCE), and for *Dehalobacter* spp. (for breakdown of 1,1,1-TCA).

Microbial Insights, Inc. (MI), of Rockford, Tennessee, will conduct the microbial DNA analyses. MI uses CENSUS® analysis to identify and quantify if microbial communities specific to reductive dechlorination are present in groundwater. The analysis involves use of a technique called quantitative polymerase chain reaction (qPCR) that places a fluorescent marker on copies of specific genes that are found in the target gene. The number of marked genes can then be quantified using a process known as Quantitative Real-Time PCR. Samples for microbial analysis will be collected in a Bio-Trap® sampler prepared by MI. The Bio-Trap® samplers will be deployed at the completion of the June 2013 groundwater sampling event, and retrieved within 45 days thereafter. The entire sampler is then preserved on ice at 4°C and shipped for

overnight delivery. The hold time is less than 48 hours. Additional information on the microbial sampling and analysis is found in Appendix B.

3.4 Sampling QA Procedures

The sample collection procedures presented in this Workplan are designed to provide samples of the required quality for evaluation of MNA in the near-field area of the site (Figure 1). All field personnel will be required to understand the requirements of this Workplan and will be trained in the use of the specified equipment and techniques.

3.4.1 General

The TRC OSC is responsible for reviewing the day-to-day activities to ensure that the procedures in the Workplan are followed. Specific activities that will be implemented by TRC include the following:

- Convene a meeting of field personnel at the start of the field efforts to review the site Health and Safety Plan (TRC, 2011a), sampling requirements of the Workplan, review the necessary equipment and decontamination requirements, and review the required field documentation procedures.
- Review all documentation during sampling events on a daily basis for completeness, errors, problems, and corrective actions taken.
- Convene daily project team meetings during sampling events at the start of the day to address any problems developed during the previous day's work, and to review the work to be completed that day.
- Manage the implementation of in-field corrective actions. The TRC Project Manager will be notified of significant problems and, if necessary, will work with the TRC OSC to develop corrective actions. The project manager will be responsible for implementing corrective actions that need to be applied to areas other than field activities.

3.4.2 Sample Collection

Personnel involved in the collection of samples are required to read, understand, and follow the procedures specified in this Workplan and associated planning documents. Problems that may affect the quality of the sampling effort will be recorded in field notebooks by the field personnel most directly involved with the sampling, and the OSC will be notified and responsible for coordinating the development and implementation of corrective actions with the TRC Project Manager.

3.5 Sample Designation

Samples will be assigned a unique alpha-numeric sample descriptor identifying the study area, media type, and sample location. Each sample will be labeled as follows:

- LTR-[sample matrix]-[sample location]-[MS/MSD or additional descriptor (if applicable)]

The “LTR” identifies the sample as coming from Lemberger Transport and Recycling Site and the associated groundwater plume. The following subsections describe the sample numbering system in greater detail. An inset in Subsection 3.5.3 shows examples of sample identification (ID) numbers for each sample type.

3.5.1 Sample Matrix

Matrix codes for the investigation include the following:

- “RM” - for groundwater samples from monitoring wells
- “EW” - for groundwater extraction well
- “OW” - for groundwater observation well
- “FB” - for field blanks
- “FDUP” - for blind field duplicate samples

3.5.2 Sample Number

Field blanks, and blind duplicate quality control samples will be numbered sequentially beginning with “001,” and will be recorded in the appropriate field notebook. For example, the complete sample identifier for the third field blank collected during this field effort would be “LTR-FB-003.” The fifth blind duplicate would be identified as “LTR-FDUP-005.” The sample that duplicate was collected for would be recorded in the field logbook and not revealed to the laboratory.

3.5.3 QA/QC Sample Identification

A sample for which additional volume is collected for matrix spike/matrix spike duplicate analyses will have the suffix of “-MS/MSD” added to the sample identification number. Example sample identifiers are given below:

Example Sample Identification Numbers

SAMPLE LOCATION	SAMPLE TYPE/MATRIX	DESCRIPTION	SAMPLE IDENTIFICATION NUMBER
RM-3XXD	Groundwater from monitoring well	Primary field sample	LTR-RM-3XXD
Field blank	QA/QC sample/water	First field blank	LTR-FB-001
Field duplicate	QA/QC sample/water	Fifth field duplicate	LTR-FDUP-005
Matrix spike/Matrix spike duplicate from well RM-401XD	QA/QC sample/water	MS/MSD	LTR-RM-401XD-MS/MSD

3.6 Chain-of-Custody Procedures

The sampler is responsible for sample custody from the time of sample collection to receipt at the laboratory or until samples are shipped by the commercial carrier. A sample is considered under custody if:

- the sample is in a person's possession,
- the sample is in that person's view after being in his or her possession,
- the sample was in that person's possession and then placed in a secured location, or
- the sample is in a designated secure area.

Sets of sample containers that are shipped together will be assigned a Chain-of-Custody form, which will travel with the sample containers. A copy of the Chain-of-Custody form with its assigned sample numbers will be kept in the laboratory to help identify samples that might become separated from the discrete sample delivery group. When shipped by a commercial carrier, custody seals will be attached to each cooler to ensure that the samples are not tampered with during transit, and the shipment airbill will be kept as Chain-of-Custody documentation. A further discussion of Chain-of-Custody procedures and a copy of the Chain-of-Custody form are included in the QAPP (TRC, 2011b).

3.7 Decontamination Procedures

Decontamination of sampling equipment is essential to ensure that constituents are not transferred from equipment to the sample or from one sample to another. Constituents can also be transferred from samplers' hands or personal protective equipment (PPE) onto sampling equipment or samples.

Samplers will use clean surgical-type nitrile gloves over their regular work gloves. At a minimum, gloves are changed after every sample site or if the gloves contact contaminated surfaces.

3.7.1 Single-Use Sampling Equipment

To the extent practicable, single-use or dedicated sampling equipment and materials will be used for the collection of samples. The materials used will be new and clean, and will be placed in plastic for transport to the site. Once used, single-use equipment will be placed in plastic bags and managed as investigation-derived waste material. Dedicated equipment will remain in the wells, or sealed in clean plastic bags for storage. Single-use equipment includes, but is not limited to, the following:

- Low-density polyethylene (LDPE), Tygon®, and silicon tubing
- Nitrile gloves
- Polypropylene rope (not expected to be needed)
- Disposable bailers (not expected to be needed)

3.7.2 Nondedicated Sampling Equipment

Proper decontamination of sampling equipment is essential to minimize the possibility of cross-contamination of samples. Nondedicated equipment used for purging monitoring wells or sampling groundwater will be cleaned before its initial use in the field and again before use at each subsequent sampling site. Equipment subject to this decontamination procedure includes, but is not limited to, the following:

- Submersible pumps
- Water level indicator
- Flow through cell
- Field parameter probes

Nondedicated sampling equipment will be new, or will be decontaminated at TRC prior to its initial use on-site and in between sampling points. Decontamination procedures will include the following steps:

- Wash the equipment in a non-phosphate detergent.
- Rinse with potable tap water.
- Rinse with deionized (DI) or distilled water.

Field decontamination of sampling equipment will take place at the sampling location. Decontamination water will be collected in 5-gallon buckets; 55-gallon drums, or

polyethylene tanks and transported to the wet well (WW-101) for disposal and treatment through the existing treatment system.

When field-cleaning of sampling equipment is required, a piece of the field-cleaned equipment will be selected for collection of a field equipment blank sample. After the piece of sampling equipment has been field-cleaned, and prior to its use for sampling, it will be rinsed with deionized water. The rinse water will be collected and submitted for analysis of all constituents for which the normal samples collected with the equipment are being analyzed. The frequency of blank collection and the analytical program for the blanks are specified in the QAPP (TRC, 2011b).

3.8 Analytical Quality Assurance Considerations

Analytical quality assurance will be discussed in detail in the QAPP (TRC, 2011b), but are summarized here as field guidance.

3.8.1 Field Duplicates

Blind field duplicate samples, prepared by splitting a single sample into two separate sets of containers, will be used to evaluate sampling precision. Points where duplicate samples are to be collected will be selected by the field personnel and will be submitted as blind duplicates to the laboratory.

3.8.2 Field Equipment Blanks

Field equipment blanks consisting of analyte-free water will be collected and submitted to the analytical laboratory to assess the quality of the data resulting from the field sampling program. Field equipment blanks are analyzed to check for procedural contamination at the site that may cause sample contamination. Field blanks will be collected following decontamination of the non-dedicated sampling equipment, including pumps. Field blanks will not be collected for disposable or dedicated sampling equipment, such as tubing dedicated to a specific well.

3.8.3 Trip Blanks

Trip blanks will be analyzed to assess whether cross-contamination of VOCs resulting from diffusion through sample container seals may have occurred during sample shipment. Trip blanks, consisting of 40-mL volatile organic analysis (VOA) vials with deionized ASTM Type 2 organic-free water, are generated in the laboratory and will accompany VOC sample coolers from the laboratory to the field and back to the laboratory. Trip blank containers are not opened in the field. Trip blanks prepared by

the laboratory will meet holding time requirements. One trip blank, consisting of two VOA vials, will be shipped with each cooler containing VOC sample containers.

3.8.4 Matrix Spikes/ Matrix Spike Duplicates (MS/MSD)

MS/MSD samples provide information about the effect of the sample matrix on the sample preparation and measurement methodology. MS/MSD samples will be analyzed for VOCs in accordance with the laboratory operating procedures provided in the QAPP. In conjunction with other QC data, the spikes and duplicates give information on the precision and accuracy of the analytical methods for the various sample matrices. One MS/MSD sample will be collected and prepared for every 20 or fewer samples collected during a sampling round. The MS/MSD samples will consist of triple the normal sample volume for VOCs, provided adequate sample volume is available. Field personnel will select the locations where MS/MSD samples are collected.

The frequencies for collection of field duplicate, field blank, trip blank, and matrix spike/matrix spike duplicate samples are specified in the QAPP, and the sample identification system is described in Subsection 3.5 of this Workplan.

Section 4

Sample Handling and Analysis

This section presents general sample handling and analysis protocols. Additional detailed information is contained in the QAPP (TRC, 2011b).

4.1 Sample Containers and Shipping

Sample containers, preservation methods, and holding times that meet USEPA standards for samples intended for chemical analyses are summarized in Table 3. For samples intended for VOC, dissolved gas, or organic carbon analysis, the sample containers will be filled completely to minimize airspace. Samples for microbial analysis will be collected by deploying a stationary collection device (Bio-Trap® filter) and submission of the filter for analysis. The sampling methodology for the microbial samples is included in Appendix B.

Samples will be kept in the dark and on ice in a metal or hard-plastic ice chest or cooler from the time the samples are collected until delivery to the laboratory.

For delivery of samples to the laboratory, the following procedures will be implemented:

1. Collect and preserve the samples as described in the QAPP. The OSC will be responsible for the proper use of containers and preservatives.
2. Place sample containers in a laboratory shipping container(s). Pack samples securely with packing material to protect sample containers from accidental breakage and from leaks or spills during shipment.
3. Fill shipping containers with enough ice to last the duration of the trip. Double-bag the ice to ensure sample integrity. Do not use dry ice and/or blue ice (ice packs).
4. Complete the Chain-of-Custody form as described in the QAPP.
5. Tape the Chain-of-Custody form to the inside of the shipping container lid.
6. Seal shipping container with strapping tape, and place a custody seal (provided by the laboratory) on the shipping container prior to shipping.
7. Deliver or ship for next day delivery to the laboratory using a common carrier, bonded courier service, or laboratory courier.

4.2 Selection of Parameters for Analysis

The samples to be collected for this data collection program will be analyzed for the parameters in Table 2. These analyses were selected based on regulatory guidance and associated technical documents (e.g., USEPA, 1998; Parsons, 2004). The number and location of the samples to be collected and the selection of parameters to be analyzed are also discussed in the QAPP.

4.3 Laboratory Analytical Procedures

The selection of analytical procedures will reflect USEPA-approved methodology from SW-846, and USEPA 300 and 600 Methods, where applicable, and as stated in the QAPP. Table 4 summarizes the analytical methods and detection limits for the MNA analytical program.

Section 5

MNA Field Data Collection

The equipment used for in-field measurement will be maintained, calibrated, and used in the field according to the procedures described in this section. The process will be documented, and the OSC will periodically review the documentation and inspect the equipment to ensure that the procedures are followed by the personnel collecting the samples. Significant deviations from the Workplan, errors, equipment failures, or other problems will be recorded in a bound notebook by the OSC and reported to the TRC Project Manager. Corrective actions and additional notifications will be coordinated by the TRC Project Manager.

5.1 Methodology

Groundwater samples will be collected using low-flow pumping techniques, as discussed in Subsection 3.2. A WTW Multi Line P3 water quality meter and flow-through cell (or equivalent) equipped with temperature, Oxidation-Reduction Potential (ORP), dissolved oxygen, specific electrical conductance, and pH electrodes will be connected to the discharge tubing from the submersible pump. Turbidity measurements will be collected from the pump discharge tubing using a Hach 2100P turbidity meter (or equivalent). The manufacturers' instructions for these instruments are included in Appendix C. Each of these parameters and the depth to water will be measured at each well during purging to evaluate stabilization. The field parameters will be considered stable when the following conditions apply between three successive 1-liter (minimum) measurement intervals:

- pH: +/- 0.1 unit
- Specific Conductivity: +/- 3%
- Temperature: +/- 0.5 degrees Celsius
- ORP: +/- 20 mV (EPA guidance suggests +/- 10 mV; site experience has found that value is often not achievable)
- DO: +/- 0.5 ppm
- Turbidity change is +/- 10% or the reading is below 10 NTU
- The water level drawdown is less than 0.16 feet in a 2-inch diameter well (or less than 0.04 feet in a 4-inch diameter well) for every liter of water removed (i.e., less than 10% of the water removed is generated from drawdown in the well casing)

The wells will be sampled immediately following stabilization. In some circumstances, where stability conditions cannot be reached, TRC will collect a sample. The decision to sample in

such an instance will be documented in the field notebook. Well sampling information will be recorded on the field logs (Appendix A). Additional low-flow purging information is provided in Appendix B.

5.2 Calibration and Measurement

The equipment will be checked for any mechanical or electrical failures, weak batteries, and cracked or fouled electrodes before mobilizing for field activities. Calibrations and repairs will be recorded in a bound notebook with the date and the name of the person making repairs/calibrations. At a minimum, the equipment will be calibrated twice each day it is in use - typically early morning and at the end of the sampling day. The end of day calibration may consist only of a check of the meters against standardized solutions. Operator's manuals for equipment typically used for sampling the Lemberger wells are included in Appendix C.

5.2.1 pH

The pH measurements will be made using a WTW Multi Line P3 water quality meter and probe (or equivalent) with its compatible flow-through cell. During use, the pH probe will be calibrated utilizing pH 4 and pH 7 buffer solutions. The pH of each sample will be measured in the flow-through cell. The pH measurements will be recorded to the nearest 0.1 pH unit. The meter will be calibrated and operated according to procedures outlined in the operations manual.

5.2.2 Specific Conductance

Specific conductance will be measured using a WTW Multi Line P3 water quality meter and probe (or equivalent). The specific conductance probe will be calibrated to a stock calibration solution. The calibration must be within 10% of the calibration value of the solution. Specific conductance measurements will be made in the flow-through cell, and are automatically corrected by the instrument to 25°C. Measurements will be reported in $\mu\text{mhos/cm}$. The meter will be calibrated and operated according to procedures outlined in the operations manual.

5.2.3 Temperature

Temperature will be measured to the nearest 0.1°C within the flow-through cell. Temperature measurements are utilized directly by the instrument to correct the specific conductance reading. The meter will be field checked in ice water and operated according to procedures outlined in the operations manual.

5.2.4 Dissolved Oxygen

Dissolved oxygen (DO) will be measured in the field using a WTW Multi Line P3 water quality meter and dissolved oxygen probe (or equivalent). Procedures for calibration and operation of the instrument with the dissolved oxygen probe are included in the manual for the meter included in Appendix C. Maintenance procedures for the probe are also included in the manufacturer's manual.

5.2.5 Oxidation-Reduction Potential

The ORP will be measured in the field using a WTW Multi Line P3 water quality meter and ORP probe (or equivalent). Procedures for calibration and operation of the instrument with the ORP probe are included in the manual included in Appendix C. Maintenance procedures for the probe are also included in the manufacturer's manual.

5.2.6 Continuous measurements

Continuous measurements of DO and water level will be collected *in-situ* from selected wells for one week during each MNA sampling event. The measurements will be collected using electronic measurement devices and data loggers described in Subsection 6.1.2. The monitoring devices will be installed at least 48 hours after the well was sampled. The purpose of this effort is to obtain more reliable DO measurements and to determine if wide variations in DO concentrations measured during the 2006-2008 MNA study are related to sampling protocol or natural variation. Monitoring devices will be placed in seven key wells for DO monitoring: RM-7D, RM-8D, RM-209D, RM-214D, RM-303D, RM-402XD, and RM-403XD. Continuous groundwater level monitoring will be included at RM-7D and RM-7XD (see Subsection 6.1.2) providing the logging transducers can successfully be placed beside the dedicated pump in well RM-7XD. The pump will not be operated while the transducer is in the well. If the transducer cannot be deployed in RM-7XD, the transducer will be placed in RM-7XXD. A barometric pressure monitor is necessary for the water level monitoring. These devices arrive with calibration documentation and will be field checked prior to deployment. The equipment used will be AquaTROLL® equipped with an optical DO sensor and a Level TROLL® for water levels. Both instruments will be rented from their manufacturer (In-Situ Inc.). Specification sheets are included in Appendix C. TRC will notify USEPA in advance if equivalent instruments are to be used.

Precipitation data will also be measured during deployment of the in-situ monitoring of DO and water levels and the microbial sampling. A simple rain gauge will be installed at the site and corroborated with data recorded from the National Weather Service for Manitowoc, Wisconsin, located approximately 10 miles southeast.

Section 6

Field Physical Measurements

Field measurements of groundwater elevations will be required during the fieldwork program. The measurements will be traceable to the person making the measurement and to the specific piece of field equipment used to make each measurement. Equipment maintenance and calibration records will be kept in field logs (Appendix A), making all such procedures traceable. Time records will be kept using local time in the 24-hour military format.

6.1 Groundwater Levels

Measurement of groundwater levels in monitoring wells will be performed prior to groundwater sampling at each well. Data from these measurements are needed to define current groundwater gradients and the direction of groundwater flow.

Groundwater level measurements are made in reference to an established reference point on the actual monitoring well casing (not on the outer protective casing). This reference point will be documented in the field records. Reference point elevations will have been previously surveyed to the NGVD. Groundwater level measurements will be made and recorded to the nearest 0.01 foot. The calculated elevations will be reported to the nearest 0.01 foot.

6.1.1 Manual Measurement Method

The depth to groundwater will be measured using an electric water level indicator. This method consists of a spool of small-diameter insulated steel cable with a probe attached to the end. A Geotech (or equivalent) water level indicator will be used. When the probe comes in contact with water, the circuit is closed and a meter, light, and/or buzzer attached to the probe signals contact with water. Batteries are normally used for a power source. Depth to water is read from permanent marks on the cable to which the probe is attached. Depth is recorded to the nearest 0.01 foot.

6.1.2 Transducer Measurement Method

Pressure transducers and a barometric pressure logger will be deployed in RM-7XD and RM-7XXD to continuously measure and record water level elevations for a minimum of one week during each of the groundwater sampling rounds. These wells were chosen because they are at the toe of the LTR, and RM-7XD has seen some increasing CVOC concentrations, which may be influenced by recharge.

Pressure transducers (Troll® manufactured by InSitu, Inc.) are capable of measuring water levels to 0.01 foot using changes in pressure. The groundwater level in the well is measured manually with an electronic tape (see previous section) and the corresponding groundwater elevation is programed into the instrument with a laptop computer. The device is then placed a minimum of two feet below the top of the groundwater surface and left to record data. When the time period is completed, the device is retrieved and the data are downloaded to the laptop. The barometric pressure logger (BaroTroll®) is compatible with the pressure transducers allowing for reliable results.

6.1.3 Quality Control Procedures

Groundwater level measuring devices will be calibrated to 0.01-foot accuracy prior to the fieldwork. Before use, these devices are prepared according to the manufacturer's instructions (if appropriate) and checked for visual damage or defects. The pressure transducers are supplied with documentation of calibration. The devices will be field tested prior to deployment by submerging them into a bucket or tube with a known depth of water and then raising them a measured amount. The transducer data will then be downloaded and checked for accuracy. If the transducer does not read accurately within 0.05 foot, it will be returned for a new device.

Section 7

Management of Waste Materials

7.1 Wastewater

All groundwater produced from well installation, development, and groundwater sampling will be collected in truck- or trailer-mounted polyethylene tanks. Smaller volumes of water, as may be generated during groundwater sampling, may be collected in 55-gallon drums or 5-gallon buckets. After each tank is filled, it will be discarded in the “wet well” at the LTR site, which formerly received the discharge from the extraction wells. The wet well includes a submersible pump that transfers the water to the influent lines at the groundwater treatment building. The total volume of groundwater produced during the proposed drilling and sampling is expected to be relatively low. The existing groundwater treatment system has ample capacity to treat the anticipated volume of drilling program groundwater, purging, and sampling.

7.2 Drill Cuttings and Samples

The amount of drill cuttings produced from sonic drilling methods are very low compared to other drilling methods. Cuttings and related investigation derived waste (IDW) will be collected in a covered plastic-lined roll-off box. After allowing solids in the drilling water to settle in the roll-off, the clarified water will be pumped into one or more polyethylene tanks, and then drained into the existing wet well at the LTR landfill. Up to an estimated 750 gallons of wastewater will be produced from each boring during drilling. A sample of the drill cutting solids will be sent for laboratory characterization to provide data to determine disposal options. Arrangements will be made in compliance with all applicable laws for off-site disposal of the solids at a licensed facility.

7.3 Used Personal Protective Equipment and Uncontaminated Refuse

Used personal protective equipment and other types of general uncontaminated debris or waste materials produced during the fieldwork will be collected daily in sealed plastic bags, and disposed of with general site refuse. The waste materials will be disposed of at the local commercial disposal facility at the end of the fieldwork.

Section 8

MNA Assessment

USEPA has defined the process and technical protocol for the use and demonstration of MNA at remediation sites, and for evaluation of the processes responsible for natural attenuation and their expected effectiveness in remediating impacted groundwater resources to achieve site-specific standards (e.g., USEPA, 1998; USEPA, 1999; USEPA, 2004a). The State of Wisconsin (WDNR, 2003) has developed their own guidance on characterizing and monitoring sites where MNA is being considered as part of an overall remediation approach. The WDNR's guidance generally conforms to USEPA's guidance and protocols. This MNA study is designed to comply with applicable USEPA and WDNR guidance and protocol documents. This section outlines how the data collected for the study will be evaluated in accordance with those documents.

8.1 MNA Data Evaluation and Reporting

The MNA data collection effort proposed in this Workplan is currently scheduled to last four quarters; however, if the LSRG believes additional data are necessary to adequately evaluate MNA as a remedy, it will propose additional monitoring at the end of the first four quarters. At the conclusion of the MNA data collection effort, the monitoring data collected from this (2013) study and the 2006 to 2008 MNA study (as appropriate) will be evaluated using methods as described in USEPA (1998), and as described in other technical references and regulatory guidance documents (e.g. USEPA, 2002; WDNR, 2003). The quantitative methods for analysis of the effects of natural attenuation processes will be applied to the demonstration project data to the extent feasible, given the physical complexities and limitations of the Lemberger sites. If additional groundwater monitoring is required, interim reports will be prepared not less than annually, within 60 days upon receipt of validated data from the latest sampling event.

8.1.1 Data Evaluation Methods

The process of data evaluation to demonstrate MNA is commonly viewed as a three stage process. The first stage or primary line of evidence focuses on the plume and its behavior (e.g., shrinking, stable, or expanding). The second stage involves observations and analysis of geochemical data that are indirect measures of bioactivity in the plume. The third line of evidence involves microbial or isotopic testing that can provide direct evidence of microbial activity. The MNA study presented in this Workplan will provide data for all three stages of evaluation.

USEPA guidance (USEPA, 1998; USEPA, 2004a) recommends establishing transects of nested wells for horizontal and vertical monitoring of contaminant plumes for MNA evaluations. Despite the uncertainty of this analysis in a fractured rock setting, this approach will be attempted as it was by USEPA (USEPA, 2010). The source area would be represented by wells OW-101A, RM-7D, RM-7XD, RM-209D, RM-303D, RM-306D, and RM-307D; a first transect comprised of RM-8D, RM-213XD, RM-402XD, RM-403XD, and RM-101D; a second transect comprised of RM-3D, EW-7D, RM-208D, and RM-214D, a “deep transect” comprised of RM-7XXD, RM-402XXD, RM-3XXD, and RM-401XXD, and a possible third (distal) transect at RM-5D, RM-401XD, and RM-204D.

8.1.2 Report Contents

At the conclusion of the MNA demonstration project, a report will be prepared. The report will include, among other things, summaries of the monitoring and measurement data from the project, technical evaluations of the data supported by tables, figures, graphs, and statistical assessments, and conclusions regarding the effectiveness and protectiveness of MNA as the long-term remedial action for groundwater at the site. Specifically, the report will contain, but will not be limited to:

- Trend plots for all 23 wells included in this MNA study. Trend lines will be included with each graph. [Note: Revised trend plots for all LTR plume wells are included with the routine groundwater monitoring reports.]
- A table with ratios of parent-to-daughter compounds for each well and each sampling event (e.g., ratio of 1,1-DCA to 1,1,1-TCA and cis-1,2-DCE to TCE).
- A table of Sen’s slope analysis for each well included in this study. Interpretations of slopes will be presented (see USEPA, 2011).
- Concentration maps for each of the MNA parameters listed in Table 2 for each sample event. Isocontours will be added to the maps, as appropriate. VOC isocontour maps will include 1,1,1-TCA, 1,1-DCA, 1,1-DCE, PCE, TCE, cis-1,2-DCE, and vinyl chloride. Summary maps may also be prepared (i.e., maximum/minimum or mean concentrations).
- A table of vertical hydraulic gradients at well nests.
- Cross-sectional views of the vertical distribution of select VOCs, inorganic constituents, and/or field parameters.
- Potentiometric surface maps.
- MNA screening as outlined in USEPA technical guidance (USEPA, 1998).
- Hydrographs from pressure transducer data.

- Graphs of continuous DO monitoring that include precipitation data and barometric pressure data.
- Analytical results of DNA analyses.
- Fence diagrams based on new transects.
- Electronic submittal of analytical data in Excel spreadsheet.

The report contents will generally include the “elements of a performance monitoring report” as defined in USEPA's guidance document “Performance Monitoring of MNA Remedies for VOCs in Ground Water” (USEPA, 2004a – Table 5). Although the report contents will generally follow the guidance document suggestions, the report will of course be organized and contain information specific to the particular conditions and circumstances at the Lemberger sites.

Section 9

Documentation and Reporting

9.1 Daily Documentation

In addition to email updates provided by the OSC or project hydrogeologist, daily field activities will be recorded in serially numbered field notebooks. The OSC will be responsible for issuing and tracking the field notebooks. Transfers of field data from other individuals (e.g., subcontractors) who have been designated to perform specific tasks on the project will be recorded. No field notes may be destroyed or thrown away, even if they are illegible, or are known to contain inaccuracies.

In addition to general notes, field personnel responsible for taking notes will log any photographs taken in the field in the field notebook. A record of where photos were taken will be recorded in the field notebook. Field maps showing the location of where the photographs are taken will be encouraged. Measurements from a photoionization detector (PID) used to screen samples and the breathing zone at the drilling site will be recorded on field log sheets. Observed potential hazards to health and safety will be described. The level of protection and the decontamination procedure used will be documented.

9.2 Data Submittals

Quarterly Data Transmittals containing the validated laboratory results and quality control (QC) descriptions for all groundwater samples collected during each calendar quarter will continue to be provided to USEPA and WDNR, following the current format for these transmittals. Copies of laboratory reports and summary tables of the validated results for residential well samples will continue to be provided to USEPA and WDNR for each sampling event.

9.3 MNA Report

Unless the LSRG believes additional monitoring is necessary as described in Section 8.1, the LSRG will prepare and submit a Draft MNA Report to USEPA within 60 working days following receipt of the fourth quarter of validated analytical data packages from the laboratory. In addition to items listed in Subsection 8.1, the report will include the following:

- A brief description of the site history and background for the site
- A description and chronology of the field activities
- Changes to the conceptual model

- An estimation of when long-term cleanup levels for the groundwater will be achieved
- Conclusions and Recommendations

9.4 Project Meetings

No on-site meetings are anticipated at this time. A kick-off meeting will be performed on-site the morning that the fieldwork is to begin to cover health and safety, drilling schedules, work limitations, communications, etc.

9.5 Data Management

A large variety and volume of data will be collected during the field efforts. Three general categories of data will be generated during these efforts, which include daily documentation, quality assurance documentation and analytical results.

9.5.1 Daily Reporting

The field personnel will record daily field activities in bound field notebooks, and will be responsible for maintaining the notebooks during construction. Hard copies of the notebooks will be provided to the On-site coordinator (OSC) and project manager as requested, and the copies will be filed. Once a notebook or the project is complete, the original notebook will be filed as a permanent record. It is the Project Manager's responsibility to ensure that the notebooks are filed correctly.

9.5.2 Quality Assurance Reporting

The OSC will be responsible for documenting site activities and ensuring compliance with the QAPP and associated planning documents. Applicable QAPP documentation will be recorded in the field notebooks. When the project is complete, the original notebooks will be filed at TRC as permanent records. It is the Project Manager's responsibility to ensure that the notebooks are filed correctly.

9.5.3 Analytical Results

Groundwater samples will be collected during the duration of the MNA demonstration project. Samples will be submitted to the USEPA-approved analytical laboratory (Pace Analytical) for analysis. The laboratory will supply data in Level III data packages. The analytical data that are generated for the groundwater samples will be maintained in the existing project database housed at TRC and portions of which are entered into the WDNR Groundwater and Environmental Monitoring System (GEMS) database. WDNR

will assign point numbers and add to GEMS the information on the seven new monitoring wells.

9.5.4 Data Validation

Data validation will be accomplished by comparing the quality assurance and quality control (QA/QC) results contained in the laboratory data packages with the requirements specified in the QAPP (TRC, 2011b); the USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review (USEPA, 2004b); the National Functional Guidelines for Organic Data Review (USEPA, 2008); and the general guidelines published in SW-846, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (USEPA, 1990 and 1996), where appropriate. One-hundred percent of the analytical laboratory data will be validated, with the exception of the microbial analysis.

9.6 Project Team Communications

Email communications between the project team members will be provided during the field effort and will include a brief summary of the activities conducted. The emails will be prepared by the TRC on-site coordinator (OSC) or project hydrogeologist with the purpose being to keep the project team informed of progress and allow input into field decisions, as necessary. The emails will typically be sent in the morning summarizing the events of the previous day and will include items such as footage drilled, wells installed, pertinent observations, problems encountered, corrective actions taken, health and safety matters, project delays, etc. All members of the project team listed in Section 10 will be included on the emails.

If significant deviations to the workplan are required based upon unanticipated and observed site conditions, the OSC will contact EPA and WDNR representatives to discuss and reach concurrence on a solution. If the regulatory agency representatives are not available within a reasonable timeframe, the OSC will proceed with the solution deemed appropriate to meet the objectives of the workplan.

Section 10

Project Team

The names, phone numbers, responsibilities, duties, qualifications, and line of authority for each role are described as follows:

- **USEPA Region V Remediation Project Manager (RPM)** – Demaree Collier is the primary USEPA Region V contact for the project. Ms. Collier will direct project activities for USEPA Region V, coordinate regulatory status and issues with USEPA Region V, and ensure that the Remedial Action complies with the Consent Order. Office # (312) 886-0214
- **Project Manager** – Kris Krause, P.E., TRC, will be the primary contact for the implementation of the Workplan, and will coordinate technical staff assignments, and establish and communicate schedules and budgets. Office # (608) 826-3637
- **USEPA Hydrologist** – David Dougherty, Subterranean Research, Inc., will serve as a technical resource for the USEPA. Mr. Dougherty will view field data, MNA analysis methods, and provide input regarding technical decisions. Office # (781) 934-7199
- **WDNR Project Manager** – Annette Weissbach, P.G. serves as WDNR's project manager and a technical resource for the project. Ms. Weissbach will review and provide comments on technical documents and represent the interests of the State. Office # (920) 662-5165; Cell # (920) 360-0853
- **Project Hydrogeologist** – James Wedekind, P.G., TRC, will serve as the Professional Geologist for the site activities as they relate to groundwater and MNA. He will be responsible for ensuring that email updates are distributed to the project team and will serve as a core member of the project team. Cell # (608) 213-3012
- **Project Quality Assurance Manager** – John Rice, P.E., TRC, will serve as a technical resource and provide quality assurance for the MNA analyses. Cell# (608) 271-6390
- **Project On-Site Coordinator (OSC)** – Meredith Westover, P.G., TRC, will serve as the OSC for the project will be responsible for coordinating the day-to-day on-site activities and will act as the field team leader. The OSC will ensure that well logs and field data documentation is prepared and complete, and will maintain field records. The OSC will also act as site health and safety officer and coordinate field crews. Cell # 608-358-5035
- **Site Manager** – Mark Brooks, TRC, serves as the site manager for the Lemberger sites. Mr. Brooks is responsible for groundwater sampling activities, site maintenance, and remediation systems maintenance. Office # (920) 732-3234
- **LSRG Representatives** – Mr. Doug Ucci of Quantum Management Group, office # (513) 871-7203, and Mr. Brian Potts of Foley and Lardner, office # (608) 258-4772, will serve as representatives of the LSRG on technical issues regarding this project. The entire LSRG may participate in discussions at their discretion.

Section 11 Schedule

A milestone schedule for each activity is estimated below. Overall the project is expected to be completed within 72 weeks from the kickoff meeting until submission of the MNA report, unless additional monitoring is necessary. The schedule assumes USEPA approval of this Workplan by November 9, 2012 in order to initiate field mobilization by November 12, 2012 (subject to subcontractor availability and the LSRG obtaining adequate property rights).

- **November 9, 2012** – Notice to Proceed
- **November 13, 2012** –Begin monitoring well installation
- **December 2012** – New monitoring well sampling
- **March/April 2013** – Well installation report
- **March 2013** – First MNA Sampling Event
- **June 2013** – Second MNA Sampling Event
- **September 2013** – Third MNA Sampling Event
- **December 2013** – Fourth MNA Sampling Event
- **April 2014** – MNA Report

Section 12

References

- B&V Waste Science and Technology Corporation (B&V). 1991. Final remedial investigation report for Lemberger Landfill, Inc. and Lemberger Transport and Recycling, Inc., sites, Volume I. January 18, 1991.
- Pankow, J.F. and J.A. Cherry. 1996. *Dense Chlorinated Solvents and Other DNAPLs in Groundwater*. Portland, Oregon, Waterloo Press. 1996.
- Parsons Corporation. 2004. Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents. Prepared for Air Force Center for Environmental Excellence Brooks City-Base, Texas, Naval Facilities Engineering Service Center Port Hueneme, California and Environmental Security Technology Certification Program Arlington, Virginia
- RMT, Inc. 2004. Assessment of Remedial Action Effectiveness. Lemberger Landfill and Lemberger Transport and Recycling Sites, Town of Franklin, Wisconsin. June 2004.
- RMT, Inc. 2008. Monitored Natural Attenuation Engineering Demonstration Project Summary Report, Lemberger Landfill and Lemberger Transport and Recycling Site, Franklin Township, Manitowoc County, Wisconsin. December 2008.
- TRC. 2011a. Health and Safety Plan. Lemberger Transport and Recycling Site, Town of Franklin, Wisconsin. March 2011.
- TRC. 2011b. Quality Assurance Project Plan. Lemberger Landfill and Lemberger Transport and Recycling Site, Town of Franklin, Wisconsin. September 2011.
- TRC. 2013 in revision. Environmental Monitoring Plan. Lemberger Landfill and Lemberger Transport and Recycling Site, Town of Franklin, Wisconsin. Revision 3. March 2013 (est.).
- USEPA. 1990. Record of Decision; Operable Unit 1; Lemberger Landfill, , Lemberger Transport & Recycling, , Manitowoc County, Wisconsin. July 2010. United States Environmental Protection Agency. September 1990.
- USEPA. 1990 and 1996. Test methods for evaluating solid waste; physical/chemical methods. SW-846.

- USEPA. 1998. Technical protocol for evaluating natural attenuation of chlorinated solvents in groundwater. United States Environmental Protection Agency. Office of Research and Development. EPA/600/R-98/128. September 1998.
- USEPA. 1999. Use of monitored natural attenuation at Superfund, RCRA Corrective Action, and underground storage tank sites. United States Environmental Protection Agency. Office of Solid Waste and Emergency Response, Directive No. 9200.4-17P. 21 April 1999.
- USEPA. 2002. Calculation and use of first-order rate constants for monitored natural attenuation studies. National Risk Management Research Laboratory. *Ground Water Issue*. EPA/540/S-02/500. November 2002.
- USEPA. 2004a. Performance monitoring of MNA remedies for VOCs in ground water. United States Environmental Protection Agency. National Risk Management Research Laboratory, Office of Research and Development. EPA/600/R-04/027. April 2004.
- USEPA. 2004b. USEPA contract laboratory program, national functional guidelines for inorganic data review. EPA/540/R-04/004. October 2004.
- USEPA. 2008. USEPA contract laboratory program, national functional guidelines for organic data review.
- USEPA. 2010. Five-year Review Report. Third Five Year Review Report for Lemberger Landfill (Lemberger Flyash) Lemberger Transport and Recycling, Franklin Township, Manitowoc County, Wisconsin. July 2010. Prepared by The United States Environmental Protection Agency, Region 5. Chicago, Illinois. July 2010.
- USEPA. 2011. An approach for evaluating the progress of natural attenuation in groundwater. EPA 600/R-11/204. Office of Research and Development National Risk Management Research Laboratory. Ada, Oklahoma. December 2011.
- WDNR. 2003. Understanding chlorinated hydrocarbon behavior in groundwater: investigation, assessment, and limitations of monitored natural attenuation. Wisconsin Department of Natural Resources. RR-699. April 2003.
- Weidemeier, T.H., M.A. Swanson, D.E. Moutoux, E.K. Gordon, J.T. Wilson, B.H. Wilson, D.H. Kampbell, J.E. Hansen, P. Haas, and F.H. Chapelle. 1995. Technical protocol for evaluating natural attenuation of chlorinated solvents in groundwater. San Antonio, Texas: Air Force Center for Environmental Excellence.

TABLES

TABLE I Summary of the data used in the study	TABLE II Summary of the data used in the study
The data were collected from a survey of 1000 people in the United Kingdom. The survey was conducted by the British Social Attitudes Survey, which is a part of the British Social Attitudes Survey. The survey was conducted in 1999 and 2000. The data were collected from a representative sample of the population. The survey was conducted by the British Social Attitudes Survey, which is a part of the British Social Attitudes Survey. The survey was conducted in 1999 and 2000. The data were collected from a representative sample of the population.	The data were collected from a survey of 1000 people in the United Kingdom. The survey was conducted by the British Social Attitudes Survey, which is a part of the British Social Attitudes Survey. The survey was conducted in 1999 and 2000. The data were collected from a representative sample of the population. The survey was conducted by the British Social Attitudes Survey, which is a part of the British Social Attitudes Survey. The survey was conducted in 1999 and 2000. The data were collected from a representative sample of the population.

Table 1
Proposed Monitoring Well Construction Summary

WELL NAME	ESTIMATED GROUND ELEVATION⁽¹⁾	ESTIMATED WELL DEPTH	ESTIMATED DEPTH OF MONITORED INTERVAL (bgs)⁽²⁾	MONITORED INTERVAL ELEVATION
RM-3XXD	820	130	120 - 130	690 - 700
RM-213XD	840	105	95 - 105	735 - 745
RM-401XD	830	95	85 - 95	735 - 745
RM-401XXD	830	140	130 - 140	690 - 700
RM-402XD	840	105	95 - 105	735 - 745
RM-402XXD	840	150	140 - 150	690 - 700
RM-403XD	840	105	95 - 105	735 - 745

Notes:

⁽¹⁾ Elevation above NGVD estimated from adjacent well and/or USGS topographic map (Whitelaw, Wis. 1978)

⁽²⁾ bgs = below ground surface

Table 2
MNA Demonstration Project
Groundwater Analytical Program

WELL DESIGNATIONS	ANALYTICAL PARAMETERS
EW-07D, OW-101A, RM-003D, <i>RM-003XXD</i> , RM-005D, RM-7D, RM-7XD, RM-7XXD, RM-008D, RM-102D, RM-204D, RM-208D, RM-209D, <i>RM-213XD</i> , RM-214D, RM-303D, RM-306D, RM-307D, <i>RM-401XD</i> , <i>RM-401XXD</i> , <i>RM-402XD</i> , <i>RM-402XXD</i> , <i>RM-403XD</i>	VOCs Dissolved gases (methane, ethane, ethene) Alkalinity Sulfate Chloride Nitrate + nitrite Total organic carbon (TOC) Total inorganic carbon (TIC) Dissolved organic carbon (DOC) Total iron Total manganese Carbon dioxide (field) Ferrous iron (field) Manganese (field) Sulfide (field) Microbial DNA (select wells only; see Subsection 3.3) Field stabilization parameters (pH, temperature, specific conductance, DO, ORP, and turbidity)

Note:

Well identifiers shown in *italics* are new monitoring wells installed as part of this Workplan.

Table 3
Analytical Methods, Sample Preservation, and Holding Times

ANALYTICAL GROUP	ANALYTICAL METHOD	SAMPLE VOLUME ⁽¹⁾	CONTAINERS (number, size, and type)	PRESERVATION REQUIREMENTS (chemical, temperature, light protected)	MAXIMUM HOLDING TIME (preparation/analysis)
VOC (monitoring wells)	SW-846 8260B	120 mL	(3) 40-mL glass vials, no headspace	Cool to 4 ± 2 °C HCl to pH <2	14 days
Dissolved gases	SW-846 8015B	120 mL	(3) 40-mL glass vials, no headspace	Cool to 4 ± 2 °C May be preserved with HCL to pH <2 (not required)	14 days
Iron, manganese (total)	SW-846 6020A	30 mL	(1) 250 mL HDPE	Cool to 4 ± 2 °C HNO ₃ to pH <2	6 months
Alkalinity	SM 2320B	100 mL	(1) 250 mL HDPE	Cool to 4 ± 2 °C	14 days
Chloride	EPA 300.0	60 mL	(1) 250 mL HDPE	Cool to 4 ± 2 °C	28 days
Sulfate	EPA 300.0	60 mL	(1) 250 mL HDPE	Cool to 4 ± 2 °C	28 days
Nitrate+nitrite	EPA 353.2	60 mL	(1) 250 mL HDPE	Cool to 4 ± 2 °C H ₂ SO ₄ to pH <2	28 days
Total organic carbon,	EPA 5310C	125 mL	(1) 125 mL amber glass, no headspace	Cool to 4 ± 2 °C H ₂ SO ₄ to pH <2	28 days
Dissolved organic carbon	EPA 5310C	125 mL	(1) 125 mL amber glass, no headspace	Cool to 4 ± 2 °C H ₂ SO ₄ to pH <2	28 days
Total inorganic carbon	EPA 5310C	125 mL	(1) 125 mL amber glass, no headspace	Cool to 4 ± 2 °C H ₂ SO ₄ to pH <2	28 days
DNA (<i>Dehalococcoides</i> spp.)	qPCR	NA	Bio-Trap [®] filter	Cool to 4 ± 2 °C	24 to 48 hours
DNA (<i>Dehalobacter</i> spp.)	qPCR	NA	Bio-Trap [®] filter	Cool to 4 ± 2 °C	24 to 48 hours

Footnote:

⁽¹⁾ The sample volume represents a recommended minimum volume. Additional sample volume may be requested by the laboratory in case of breakage. Sample volume for multiple analyses may be combined into a single jar of adequate volume

Table 4
Monitored Natural Attenuation Parameters, Analytical Methods, and Reporting Limits

GROUNDWATER PARAMETER	FIELD OR LABORATORY	METHOD	EQUIPMENT	LIMIT OF DETECTION (LOD) ⁽⁵⁾	LIMIT OF QUANTITATION (LOQ)	MNA SCREENING CONCENTRATION (EPA 1998)
Carbon dioxide	Field	ASTM D 513-82	Colorimetric	10 mg/L	10 - 100 mg/L	>2X background
Dissolved oxygen	Field	360.1 ⁽¹⁾	Probe	0.1 mg/L ⁽⁴⁾	N/A	<0.5 mg/L
Dissolved oxygen	Field	In Situ Method 1002-8-2009	Optical Probe with data logger	0.01 mg/L ⁽⁴⁾	0.1 mg/L	<0.5 mg/L
Ferrous iron	Field	ASTM D 1068-77 (Phenanthroline)	Colorimetric	0.05 mg/L	0-1 mg/L	>1 mg/L
Manganese	Field	Periodate Method	Colorimetric	0.15 mg/L	0.3 mg/L	N/A
Oxidation reduction potential	Field	Standard methods ⁽²⁾	Electrode	N/A	20 mV	<50 mV
pH	Field	150.1 ⁽¹⁾	Electrode	N/A	0.1 standard units	5 – 9
Specific conductivity	Field	120.1 ⁽¹⁾	Meter	N/A	1 µmhos/cm	N/A
Sulfide	Field	EPA 376.2 (methylene blue)	Colorimetric	0.05 mg/L	0-1 mg/l	>1 mg/L
Temperature	Field	--	Probe	N/A	0.1°C	>20° C
Turbidity	Field	SM 2130B	Meter	NA	1 NTU	N/A
Alkalinity (total)	Laboratory	2320B ⁽²⁾	Per method	1.8 mg/L	10 mg/L	>2X background
Chloride	Laboratory	300.0 ⁽¹⁾	Per method	2.0 mg/L	4.0 mg/L	>2X background
Ethane	Laboratory	M8015B ⁽³⁾	Per method	0.32 µg/L	5.0 µg/L	>0.01 mg/L
Ethene	Laboratory	M8015B ⁽³⁾	Per method	0.47 µg/L	5.6 µg/L	>0.01 mg/L
Manganese	Laboratory	6020 ⁽³⁾	Per method	0.36 µg/L	1.0 µg/L	N/A >background
Total Iron	Laboratory	6020 ⁽³⁾	Per method	7.84 µg/L	250 µg/L	N/A
Methane	Laboratory	M8015B ⁽³⁾	Per method	0.93 µg/L	2.8 µg/L	>0.5 mg/L
Nitrate + nitrite	Laboratory	353.2 ⁽¹⁾	Per method	0.125 mg/L	0.25 mg/L	<1.0 mg/L
Sulfate	Laboratory	300.0 ⁽¹⁾	Per method	2.0 mg/L	4.0 mg/L	< 20 mg/L
Total organic carbon (TOC)	Laboratory	EPA 5310C	Per method	0.07 mg/L	0.5 mg/L	> 20 mg/L

Table 4 (continued)
Monitored Natural Attenuation Parameters, Analytical Methods, and Reporting Limits

GROUNDWATER PARAMETER	FIELD OR LABORATORY	METHOD	EQUIPMENT	LIMIT OF DETECTION (LOD) ⁽⁵⁾	LIMIT OF QUANTITATION (LOQ)	MNA SCREENING CONCENTRATION (EPA 1998)
Total inorganic carbon (TIC)	Laboratory	EPA 5310C	Per method	0.07 mg/L	0.5 mg/L	N/A >background
Dissolved organic carbon (DOC)	Laboratory	EPA 5310C	Per method	0.07 mg/L	0.5 mg/L	>20 mg/L
Volatile organic compounds (VOCs)	Laboratory	SW-846 8260B	Per method	As per QAPP	As per QAPP	Presence of daughter products
Low-level Vinyl Chloride	Laboratory	EPA 8260B	Per method	0.01 µg/L	0.032 µg/L	Detection
DNA (<i>Dehalococcoides</i> <i>spp.</i>)	Laboratory	qPCR ⁽⁶⁾	Per method	If present	If present	500 cells/sample
DNA (<i>Dehalobacter</i> <i>spp.</i>)	Laboratory	qPCR ⁽⁶⁾	Per method	If present	If present	3,000 cells/sample

Notes:

⁽¹⁾ USEPA 600/4-79-020, Methods for Chemical Analysis of Water and Waste.

⁽²⁾ Standard Methods for the Examination of Water and Wastewater, 19th Edition, 1995.

⁽³⁾ SW-846, Test Methods for Evaluating Solid Waste, Physical and Chemical Methods, USEPA, 3rd Edition, 1986.)

⁽⁴⁾ Based on typical field meter and dissolved oxygen probe with a resolution of 0.01 mg/L and used under normal field operating conditions.

⁽⁵⁾ Limits are periodically updated by the laboratory. The current limits at the time of sample analysis will be used.

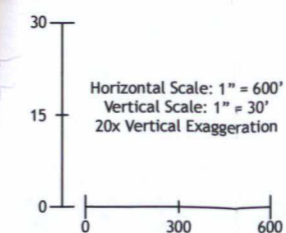
⁽⁶⁾ Quantitative real-time polymerase chain reaction.

N/A = not applicable or no standard.

FIGURES



SOUTH - A'



— STRATIGRAPHIC BOUNDARY, DASHED
WHERE INFERRED

 UPPER GRANULAR UNIT

 CLAY CONFINING UNIT

 LOWER GRANULAR UNIT

 DOLOMITE BEDROCK

 WATER TABLE

(6.2) TCE CONCENTRATION ($\mu\text{g/L}$) - PACKER DATA,
SAMPLED SEPTEMBER 2008

41.7 TCE CONCENTRATION ($\mu\text{g/L}$) - WELL DATA, SAMPLED MARCH 2012
EXCEPT RM-7S AND RM-20BS SAMPLED SEPTEMBER 2011,
AND EW-1D AND EW-7D SAMPLED JULY 2008

— TCE ES ISCONCENTRATION ($5 \mu\text{g/L}$)

WELL CONSTRUCTION DETAILS

 WELL CASING

 WELL SEAL

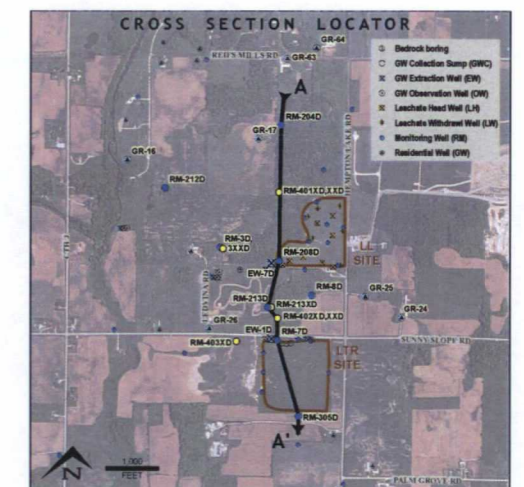
 WELL SCREEN

 OPEN HOLE (NO SCREEN)

 WELL IN CROSS SECTION PLANE

 WELL PROJECTED ONTO CROSS SECTION

1. GROUNDWATER ELEVATIONS WERE MEASURED JULY 3, 2008.
2. GROUNDWATER ANALYTICAL RESULTS ARE FROM THE MOST RECENT SAMPLING EVENT AT THAT WELL.
3. PROPOSED WELLS ARE SHADED.



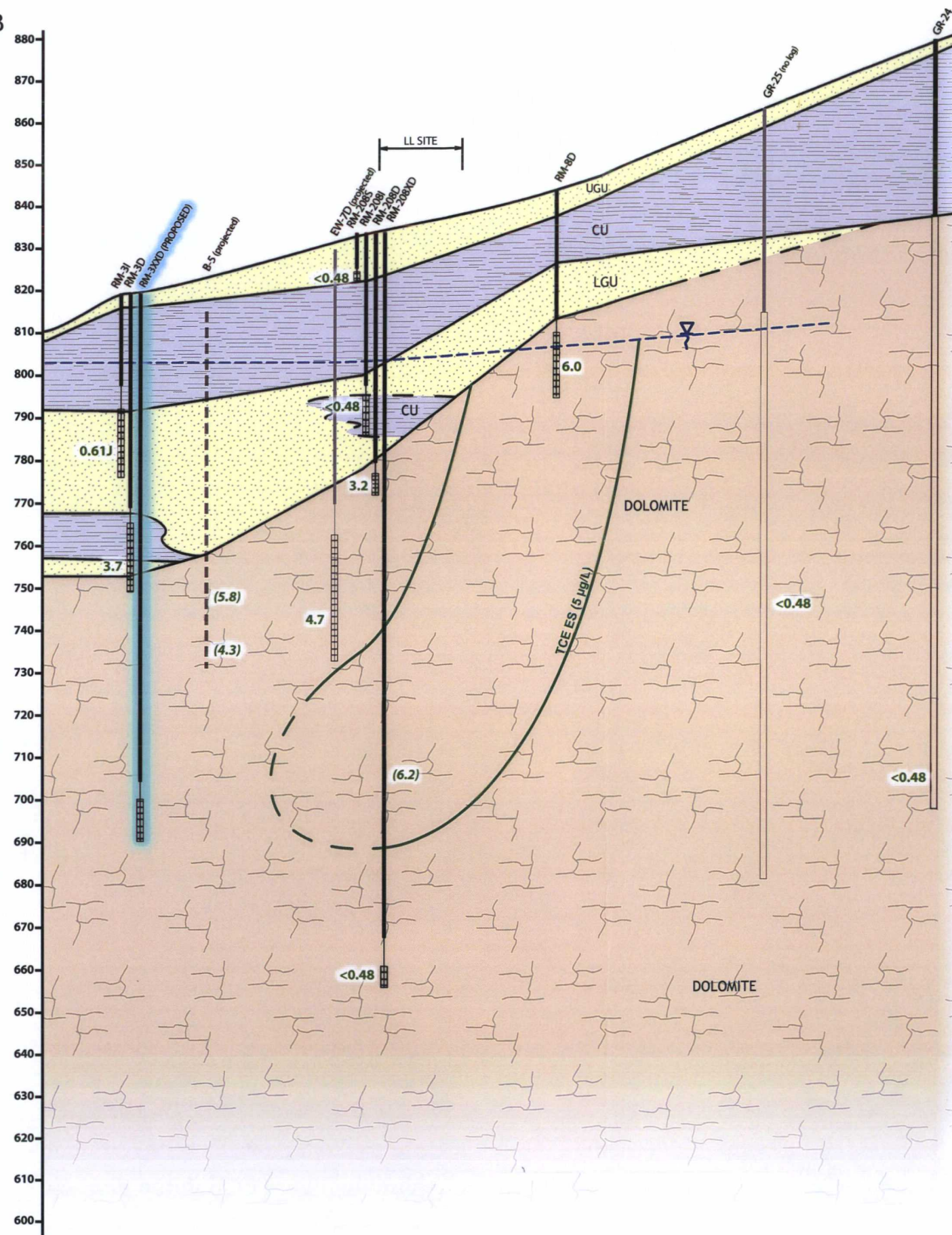
PROJECT:		MNA WORKPLAN LEMBERGER SITES TOWN OF FRANKLIN, WISCONSIN	
SHEET TITLE: CROSS SECTION A - A'			
DRAWN BY:	PAPEZ J	SCALE:	PROJ. NO. 195845-001
CHECKED BY:	WEDEKIND J	AS NOTED	FILE NO. 195845.001.a01.xls
APPROVED BY:	KRAUSE K	DATE PRINTED:	FIGURE 2
DATE:	FEBRUARY 2013	FEB 28 2013	



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WEST - B

ELEVATION (FEET ABOVE M.S.L.)



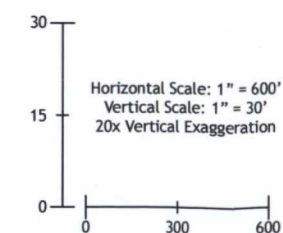
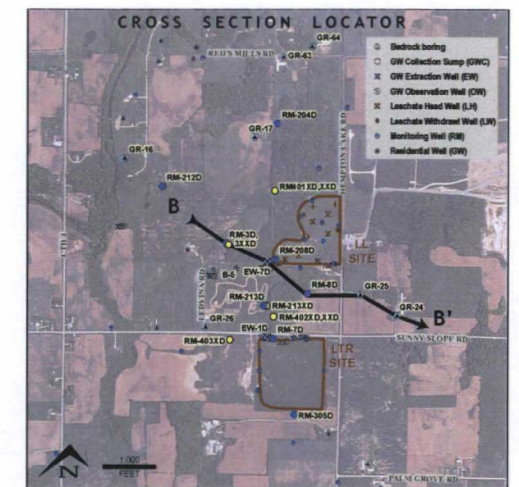
EAST - B'

LEGEND

- STRATIGRAPHIC BOUNDARY, DASHED WHERE INFERRED
- UGU UPPER GRANULAR UNIT
- CU CLAY CONFINING UNIT
- LGU LOWER GRANULAR UNIT
- DOLOMITE BEDROCK
- WATER TABLE
- (6.2) TCE CONCENTRATION (µg/L) - PACKER DATA, SAMPLED SEPTEMBER 2008
- 4.7 TCE CONCENTRATION (µg/L) - WELL DATA, SAMPLED MARCH 2012 EXCEPT RM-31 AND RM-208S SAMPLED SEPTEMBER 2011, AND EW-7D SAMPLED JULY 2008
- TCE ES ISCONCENTRATION (5 µg/L)
- WELL CONSTRUCTION DETAILS
- WELL CASING
- WELL SEAL
- WELL SCREEN
- OPEN HOLE (NO SCREEN)
- WELL IN CROSS SECTION PLANE
- WELL PROJECTED ONTO CROSS SECTION

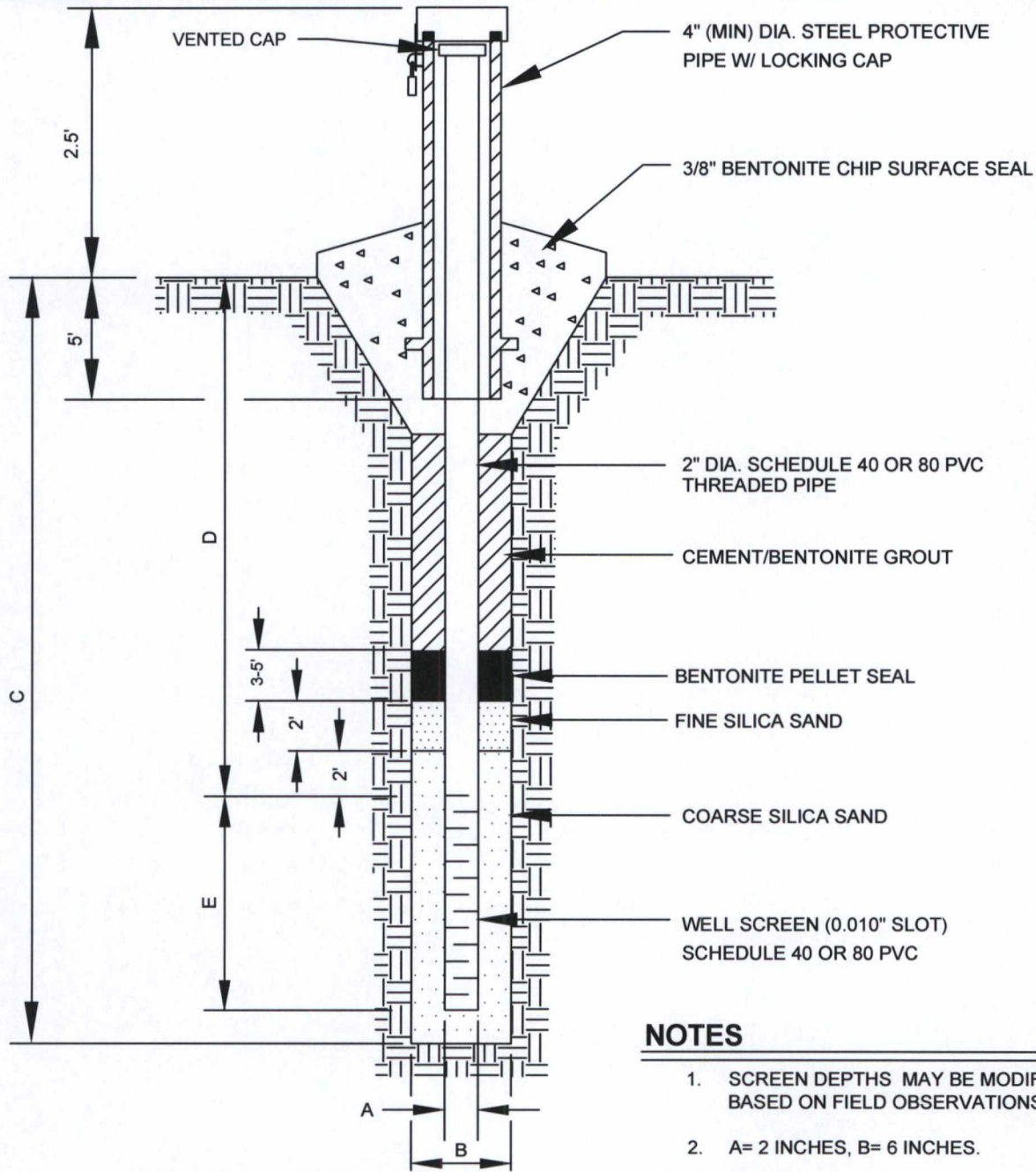
NOTES

1. GROUNDWATER ELEVATIONS WERE MEASURED JULY 3, 2008.
2. GROUNDWATER ANALYTICAL RESULTS ARE FROM THE MOST RECENT SAMPLING EVENT AT THAT WELL.
3. PROPOSED WELLS ARE SHADED.



E:\LembergerLandfill\2012_195845\AI\195845.001.ai02.ai

PROJECT: MNA WORKPLAN LEMBERGER SITES TOWN OF FRANKLIN, WISCONSIN			
SHEET TITLE: CROSS SECTION B - B'			
DRAWN BY: PAPEZ J	SCALE: AS NOTED	PROJ. NO. 195845-001	FIGURE 3
CHECKED BY: WEDEKIND J	DATE PRINTED: FEBRUARY 2013	FILE NO. 195845.001.ai02.ai	
APPROVED BY: KRAUSE K	DATE: FEBRUARY 2013		
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NOTES

1. SCREEN DEPTHS MAY BE MODIFIED BASED ON FIELD OBSERVATIONS.
2. A= 2 INCHES, B= 6 INCHES.

WELL NAME	GROUND ELEVATION ⁽¹⁾	ESTIMATED WELL DEPTH	ESTIMATED DEPTH OF MONITORED INTERVAL (bgs) ⁽²⁾	MONITORED INTERVAL ELEVATION
RM-3XXD	818	128	118 - 128	690 - 700
RM-213XD	840	105	95 - 105	735 - 745
RM-401XD	831	96	86 - 96	735 - 745
RM-401XXD	830	140	130 - 140	690 - 700
RM-402XD	839	104	94 - 104	735 - 745
RM-402XXD	839	149	139 - 149	690 - 700
RM-403XD	842	107	97 - 107	735 - 745



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PROJECT:

**LEMBERGER LANDFILL AND
 TRANSFER AND RECYCLING SITES
 TOWN OF FRANKLIN, WISCONSIN**

SHEET TITLE:

**MNA WORKPLAN
 TYPICAL MONITORING WELL CONSTRUCTION**

DRAWN BY:

LSTORMER

APPROVED BY:

JW

PROJ. NO.

195845.0001

FILE NO.

195845.0001.01.dwg

DATE:

FEBRUARY 2013

FIGURE 4



LEGEND

SAMPLE AND MONITORING LOCATIONS

- ⊕ BEDROCK BORING
- GW COLLECTION SUMP (GWC)
- ⊗ GW EXTRACTION WELL (EW)
- GW OBSERVATION WELL (OW)
- ⊗ LEACHATE HEAD WELL (LH)
- ⊕ LEACHATE WITHDRAWL WELL (LW)
- MONITORING WELL (RM)
- RESIDENTIAL WELL (GR)
- ⊕ PROPOSED MONITORING WELL



LIMITS OF WASTE



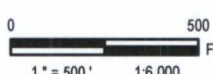
PROPOSED DMZ



MNA STUDY SAMPLE LOCATION
(YELLOW HIGHLIGHT)

NOTES

1. BASE MAP IMAGERY FROM MANTOWOC COUNTY, 2010.
2. MAP COORDINATES ARE WISCONSIN STATE PLANE, SOUTH ZONE, NAD 83, US SURVEY FOOT.



PROJECT:

**MNA WORKPLAN
LEMBERGER SITES
TOWN OF FRANKLIN, WISCONSIN**

SHEET TITLE:

**MONITORING WELLS INCLUDED IN THE
MNA DEMONSTRATION STUDY**

DRAWN BY: PAPEZ J

SCALE:

PROJ. NO.

195845-001

CHECKED BY: WEDEKIND J

AS NOTED

FILE NO.

195845.01.002.mxd

APPROVED BY: KRAUSE K

DATE PRINTED:

FIGURE 5

DATE: FEBRUARY 2013

FEB 28 2013



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Appendix A

Examples of Forms/Logs



PROJECT NAME:	_____
PROJECT NUMBER:	_____
PROJECT MANAGER:	_____
SITE LOCATION:	_____ _____
DATES OF FIELDWORK:	_____ _____ _____
PURPOSE OF FIELDWORK:	_____ _____ _____ _____ _____ _____ _____ _____ _____ _____
WORK PERFORMED BY:	_____ _____ _____ _____ _____

SIGNED

DATE _____

CHECKED BY

DATE _____



GENERAL NOTES

PROJECT NAME:	DATE:	TIME ARRIVED:
PROJECT NUMBER:	AUTHOR:	TIME LEFT:

[illegible]

PROBLEMS ENCOUNTERED	CORRECTIVE ACTION TAKEN

[illegible]

SIGNED

DATE _____

CHECKED BY

DATE _____



WATER QUALITY METER CALIBRATION LOG

PROJECT NAME:	MODEL:	SAMPLER:
PROJECT NO.:	SERIAL #:	DATE:

PH CALIBRATION CHECK

pH 7 (LOT #): (EXP. DATE):	pH 4 / 10 (LOT #): (EXP. DATE):	CAL. RANGE	TIME
POST-CAL. READING / STANDARD	POST-CAL. READING / STANDARD		
/	/	<input type="checkbox"/> WITHIN RANGE	
/	/	<input type="checkbox"/> WITHIN RANGE	
/	/	<input type="checkbox"/> WITHIN RANGE	
/	/	<input type="checkbox"/> WITHIN RANGE	

SPECIFIC CONDUCTIVITY CALIBRATION CHECK

CAL. READING (LOT #): (EXP. DATE):	TEMPERATURE (°CELSIUS)	CAL. RANGE	TIME
POST-CAL. READING / STANDARD			
/		<input type="checkbox"/> WITHIN RANGE	
/		<input type="checkbox"/> WITHIN RANGE	
/		<input type="checkbox"/> WITHIN RANGE	
/		<input type="checkbox"/> WITHIN RANGE	

ORP CALIBRATION CHECK

CAL. READING (LOT #): (EXP. DATE):	TEMPERATURE (°CELSIUS)	CAL. RANGE	TIME
POST-CAL. READING / STANDARD			
/		<input type="checkbox"/> WITHIN RANGE	
/		<input type="checkbox"/> WITHIN RANGE	
/		<input type="checkbox"/> WITHIN RANGE	
/		<input type="checkbox"/> WITHIN RANGE	

D.O. CALIBRATION CHECK

CALIBRATION READING (mg/L)	CAL. RANGE	TIME
	<input type="checkbox"/> WITHIN RANGE	
	<input type="checkbox"/> WITHIN RANGE	
	<input type="checkbox"/> WITHIN RANGE	
	<input type="checkbox"/> WITHIN RANGE	

TURBIDITY CALIBRATION CHECK

CALIBRATION READING (NTU)		CAL. RANGE	TIME
(LOT #): (EXP. DATE):	(LOT #): (EXP. DATE):		
POST-CAL. READING / STANDARD	POST-CAL. READING / STANDARD		
/	/	<input type="checkbox"/> WITHIN RANGE	
/	/	<input type="checkbox"/> WITHIN RANGE	
/	/	<input type="checkbox"/> WITHIN RANGE	
/	/	<input type="checkbox"/> WITHIN RANGE	

COMMENTS

<input type="checkbox"/> AUTOCAL SOLUTION	<input type="checkbox"/> STANDARD SOLUTION (S)
(LOT #): (EXP. DATE):	LIST LOT NUMBERS AND EXPIRATION DATES UNDER CALIBRATION CHECK
CALIBRATED PARAMETERS	CALIBRATION RANGES ⁽¹⁾
<input type="checkbox"/> pH	pH: +/- 0.2 S.U.
<input type="checkbox"/> COND	COND: +/- 1% OF CAL. STANDARD
<input type="checkbox"/> ORP	ORP: +/- 25 mV
<input type="checkbox"/> D.O.	D.O.: VARIES
<input type="checkbox"/> TURB	TURB: +/- 5% OF CAL. STANDARD
<input type="checkbox"/> _____	⁽¹⁾ CALIBRATION RANGES ARE SPECIFIC TO THE MODEL OF THE WATER QUALITY METER
<input type="checkbox"/> _____	

NOTES

PROBLEMS ENCOUNTERED	CORRECTIVE ACTIONS

SIGNED

DATE

CHECKED BY

DATE



PID FIELD CALIBRATION LOG

PROJECT NAME:	MODEL:
PROJECT NUMBER.:	LAMP VOLTAGE:
SAMPLER NAME:	SERIAL NO.:

PID CALIBRATION CHECK

	DATE: TIME: INITIALS:	DATE: TIME: INITIALS:	DATE: TIME: INITIALS:	DATE: TIME: INITIALS:	DATE: TIME: INITIALS:
BATTERY CHECK	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ZERO GAS	/	/	/	/	/
SPAN GAS	/	/	/	/	/
AUDIBLE FAN MOTOR CHECK	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RESPONSE CHECK	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

NOTES

PROBLEMS ENCOUNTERED	CORRECTIVE ACTION

SIGNED _____ DATE _____

CHECKED _____ DATE _____

[illegible]

SIGNED

DATE _____

CHECKED

DATE _____



WATER SAMPLE LOG

PROJECT NAME:				PREPARED				CHECKED			
PROJECT NUMBER:				BY:		DATE:		BY:		DATE:	
SAMPLE ID:				WELL DIAMETER: <input type="checkbox"/> 2" <input type="checkbox"/> 4" <input type="checkbox"/> 6" <input type="checkbox"/> OTHER _____							
WELL MATERIAL: <input type="checkbox"/> PVC <input type="checkbox"/> SS <input type="checkbox"/> IRON <input type="checkbox"/> GALVANIZED STEEL <input type="checkbox"/> OTHER _____											
SAMPLE TYPE: <input type="checkbox"/> GW <input type="checkbox"/> WW <input type="checkbox"/> SW <input type="checkbox"/> DI <input type="checkbox"/> LEACHATE <input type="checkbox"/> OTHER _____											
PURGING		TIME:		DATE:		SAMPLE		TIME:		DATE:	
PURGE METHOD: <input type="checkbox"/> PUMP <input type="checkbox"/> BAILER _____						PH: _____ SU		CONDUCTIVITY: _____ umhos/cm			
						DO: _____ mg/l		Eh: _____ MV			
DEPTH TO WATER: _____ T/ PVC				TURBIDITY: _____ NTU <input type="checkbox"/> NONE <input type="checkbox"/> SLIGHT <input type="checkbox"/> MODERATE <input type="checkbox"/> VERY							
DEPTH TO BOTTOM: _____ T/ PVC											
WELL VOLUME: _____ LITERS <input type="checkbox"/> GALLONS				TEMPERATURE: _____ °C				OTHER: _____			
VOLUME REMOVED: _____ LITERS <input type="checkbox"/> GALLONS				COLOR: _____				ODOR: _____			
COLOR: _____ ODOR: _____				FILTRATE (0.45 um) <input type="checkbox"/> YES <input type="checkbox"/> NO							
TURBIDITY <input type="checkbox"/> NONE <input type="checkbox"/> SLIGHT <input type="checkbox"/> MODERATE <input type="checkbox"/> VERY				FILTRATE COLOR: _____				FILTRATE ODOR: _____			
DISPOSAL METHOD: <input checked="" type="checkbox"/> GROUND <input type="checkbox"/> DRUM <input type="checkbox"/> OTHER				QC SAMPLE: <input type="checkbox"/> MS/MSD <input type="checkbox"/> DUP- _____							
				COMMENTS: _____							
TIME	PURGE RATE (ML/MIN)	TEMPERATURE (°C)	CONDUCTIVITY (umhos/cm)	D.O. (mg/L)	pH (SU)	ORP (mV)	TURBIDITY (NTU)	WATER LEVEL (FEET)	CUMULATIVE PURGE VOLUME (GAL OR L)		
									INITIAL		
BOTTLES FILLED		PRESERVATIVE CODES A - NONE B - HNO3 C - H2SO4 D - NaOH E - HCL F - _____									
NUMBER	SIZE	TYPE	PRESERVATIVE	FILTERED	NUMBER	SIZE	TYPE	PRESERVATIVE	FILTERED		
				<input type="checkbox"/> Y <input type="checkbox"/> N					<input type="checkbox"/> Y <input type="checkbox"/> N		
				<input type="checkbox"/> Y <input type="checkbox"/> N					<input type="checkbox"/> Y <input type="checkbox"/> N		
				<input type="checkbox"/> Y <input type="checkbox"/> N					<input type="checkbox"/> Y <input type="checkbox"/> N		
				<input type="checkbox"/> Y <input type="checkbox"/> N					<input type="checkbox"/> Y <input type="checkbox"/> N		
				<input type="checkbox"/> Y <input type="checkbox"/> N					<input type="checkbox"/> Y <input type="checkbox"/> N		
SHIPPING METHOD: _____		DATE SHIPPED: _____									
		SIGNATURE: _____				DATE SIGNED: _____					

Page _____ of _____

[illegible]

Signature	Firm
-----------	------

This form is authorized by Chapters 281, 283, 289, 291, 292, 293, 295, and 299, Wis. Stats. Completion of this form is mandatory. Failure to file this form may result in forfeiture of between \$10 and \$25,000, or imprisonment for up to one year, depending on the program and conduct involved. Personally identifiable information on this form is not intended to be used for any other purpose. NOTE: See instructions for more information, including where the completed form should be sent.

Route to: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

MONITORING WELL CONSTRUCTION
Form 4400-113A Rev. 7-98

Facility/Project Name		Local Grid Location of Well _____ ft. <input type="checkbox"/> N. _____ ft. <input type="checkbox"/> E. _____ ft. <input type="checkbox"/> S. _____ ft. <input type="checkbox"/> W.		Well Name	
Facility License, Permit or Monitoring No.		Local Grid Origin <input type="checkbox"/> (estimated: <input type="checkbox"/>) or Well Location <input type="checkbox"/> Lat. _____ " Long. _____ " or _____		Wis. Unique Well No. _____ DNR Well ID No. _____	
Facility ID		St. Plane _____ ft. N. _____ ft. E. S/C/N		Date Well Installed ____/____/____	
Type of Well		Section Location of Waste/Source 1/4 of _____ 1/4 of Sec. _____ T. _____ N, R. _____ <input type="checkbox"/> E <input type="checkbox"/> W		Well Installed By: Name (first, last) and Firm _____	
Well Code _____ / _____		Location of Well Relative to Waste/Source u <input type="checkbox"/> Upgradient s <input type="checkbox"/> Sidegradient d <input type="checkbox"/> Downgradient n <input type="checkbox"/> Not Known		Gov. Lot Number _____	
Distance from Waste/Source _____ ft.		Enf. Stds. Apply <input type="checkbox"/>			

A. Protective pipe, top elevation _____ ft. MSL

B. Well casing, top elevation _____ ft. MSL

C. Land surface elevation _____ ft. MSL

D. Surface seal, bottom _____ ft. MSL or _____ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis performed? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐ 50
Hollow Stem Auger ☐ 41
Other ☐

15. Drilling fluid used: Water ☐ 02 Air ☐ 01
Drilling Mud ☐ 03 None ☐ 99

16. Drilling additives used? ☐ Yes ☐ No

Describe _____

17. Source of water (attach analysis, if required):

E. Bentonite seal, top _____ ft. MSL or _____ ft.

F. Fine sand, top _____ ft. MSL or _____ ft.

G. Filter pack, top _____ ft. MSL or _____ ft.

H. Screen joint, top _____ ft. MSL or _____ ft.

I. Well bottom _____ ft. MSL or _____ ft.

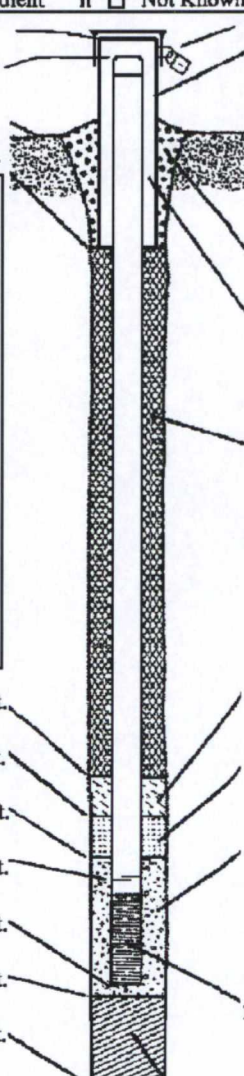
J. Filter pack, bottom _____ ft. MSL or _____ ft.

K. Borehole, bottom _____ ft. MSL or _____ ft.

L. Borehole, diameter _____ in.

M. O.D. well casing _____ in.

N. I.D. well casing _____ in.



1. Cap and lock? ☐ Yes ☐ No

2. Protective cover pipe:
a. Inside diameter: _____ in.
b. Length: _____ ft.
c. Material: Steel ☐ 04
Other ☐
d. Additional protection? ☐ Yes ☐ No
If yes, describe: _____

3. Surface seal: Bentonite ☐ 30
Concrete ☐ 01
Other ☐

4. Material between well casing and protective pipe:
Bentonite ☐ 30
Other ☐

5. Annular space seal: a. Granular/Chipped Bentonite ☐ 33
b. _____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐ 35
c. _____ Lbs/gal mud weight Bentonite slurry ☐ 31
d. _____ % Bentonite Bentonite-cement grout ☐ 50
e. _____ Ft³ volume added for any of the above
f. How installed: Tremie ☐ 01
Tremie pumped ☐ 02
Gravity ☐ 08

6. Bentonite seal: a. Bentonite granules ☐ 33
b. ☐ 1/4 in. ☐ 3/8 in. ☐ 1/2 in. Bentonite chips ☐ 32
c. _____ Other ☐

7. Fine sand material: Manufacturer, product name & mesh size
a. _____
b. Volume added _____ ft³

8. Filter pack material: Manufacturer, product name & mesh size
a. _____
b. Volume added _____ ft³

9. Well casing: Flush threaded PVC schedule 40 ☐ 23
Flush threaded PVC schedule 80 ☐ 24
Other ☐

10. Screen material:
a. Screen type: Factory cut ☐ 11
Continuous slot ☐ 01
Other ☐
b. Manufacturer _____
c. Slot size: _____ 0. _____ in.
d. Slotted length: _____ ft.

11. Backfill material (below filter pack): None ☐ 14
Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature _____ Firm _____

Route to: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	County Name	Well Name	
Facility License, Permit or Monitoring Number	County Code	Wis. Unique Well Number	DNR Well ID Number

1. Can this well be purged dry? ☐ Yes ☐ No

2. Well development method

- surged with bailer and bailed ☐ 4 1
surged with bailer and pumped ☐ 6 1
surged with block and bailed ☐ 4 2
surged with block and pumped ☐ 6 2
surged with block, bailed and pumped ☐ 7 0
compressed air ☐ 2 0
bailed only ☐ 1 0
pumped only ☐ 5 1
pumped slowly ☐ 5 0
Other ☐

3. Time spent developing well _____ min.

4. Depth of well (from top of well casing) _____ ft.

5. Inside diameter of well _____ in.

6. Volume of water in filter pack and well casing _____ gal.

7. Volume of water removed from well _____ gal.

8. Volume of water added (if any) _____ gal.

9. Source of water added _____

10. Analysis performed on water added? ☐ Yes ☐ No
(If yes, attach results)

17. Additional comments on development:

	Before Development	After Development
11. Depth to Water (from top of well casing)	a. _____ ft.	_____ ft.
Date	b. ____/____/____	____/____/____
Time	c. ____:____ <input type="checkbox"/> a.m. <input type="checkbox"/> p.m.	____:____ <input type="checkbox"/> a.m. <input type="checkbox"/> p.m.
12. Sediment in well bottom	_____ inches	_____ inches
13. Water clarity	Clear <input type="checkbox"/> 1 0 Turbid <input type="checkbox"/> 1 5 (Describe) _____	Clear <input type="checkbox"/> 2 0 Turbid <input type="checkbox"/> 2 5 (Describe) _____

Fill in if drilling fluids were used and well is at solid waste facility:

14. Total suspended solids _____ mg/l _____ mg/l

15. COD _____ mg/l _____ mg/l

16. Well developed by: Name (first, last) and Firm

First Name: _____ Last Name: _____

Firm: _____

Name and Address of Facility Contact /Owner/Responsible Party

First Name: _____ Last Name: _____
Name: _____

Facility/Firm: _____

Street: _____

City/State/Zip: _____

I hereby certify that the above information is true and correct to the best of my knowledge.

Signature: _____

Print Name: _____

Firm: _____

Completion of this form is mandatory under a NR 507.14 and NR 110.25 Wis. Adm. Code. Failure to file this form may result in penalties of not less than \$10 nor more than \$5,000 for each day of violation. Personally identifiable information provided is intended to be used by the Department for the purposes related to the waste management program.

**INSTRUCTIONS FOR GROUNDWATER MONITORING
WELL INFORMATION FORM 4400-89**

This form, when completed provides a record of information for each well or sampling point that is part of a facility's groundwater monitoring program. It provides the facility or consultant with a means of presenting in a consistent format the well data which the department requires during a site review process. It should be updated as new wells are added to the monitoring program.

Each element of the form is described below. Complete the form with the necessary information, using the description of the elements as a guide.

Facility Name: The name of the site or landfill.

Facility ID Number: Fill in the nine digit Facility ID (FID) assigned to the site.

License/Permit/Monitoring Number: The number assigned by the Department to the facility.
If unknown, leave blank.

Date: The date on which the form is filled out (mm/dd/yyyy).

Completed By: The name and firm of person completing the form.

WI Unique Well No: The Wisconsin Unique Well Number assigned to the well. These numbers are available from the Department and are to be assigned to all newly drilled wells.

Well Name: The common well name given to the well by the facility or consultant; e.g. MW-21 OW-5.

DNR Well ID Number: The 3 digit number assigned to the well by the Department, for use by the Department.

Well Location: The location of the well, measured in feet, in relation to a grid system origin established for the site or state plane coordinate system.

Dir: The location direction for the well relative to the grid origin. If state plane coordinates are used these should be N and E.

Date Established: The installation date of the well.

Well Casing Diam.: The inside diameter of the pipe used in the well construction, in inches.

Well Casing Type: The type of pipe used: plastic (P), steel (S), or other (O).

Elevations:

Top of Well Casing: The elevation, of the top of the well casing (not top of protective pipe), in feet.

Ground Surface: The elevation, in feet, of the ground surface adjacent to the well.

Reference: Are elevations referenced to Mean Sea Level (MSL) or to a particular site datum established for the facility or site. Check one or the other.

Depths:

Screen Top: The depth, in feet, to the well screen top (subtract the screen length from the well depth).

Initial Groundwater: The depth, in feet, to the water level in the well before well development.

Well Depth: The total depth of the well from the top of well casing, measured in feet.

Screen Length: The length of the screen measured in feet.

Well Type: Record the type of well or sampling point code (number/initials) from the following list:

- 11/mw Water table observation well (monitoring well screen intersecting the water table) (non Subtitle D well)
- 12/pz Piezometer (monitoring well with screen sealed below the water table) (non Subtitle D well)
- 13/pw Private well - potable water supply
- 14/ly Lysimeter
- 16/rp Resistivity probe
- 17/gc Gradient control
- 18/at Aquifer test well
- 22/sw Surface water
- 23/lc Leachate collection system
- 24/lh Leachate head well
- 25/lg Leachate and Gas combo
- 26/ew Groundwater extraction well
- 27/he Horizontal groundwater extraction well
- 28/hw Horizontal monitoring well
- 29/ha Horizontal vapor extraction well
- 31/us Upstream
- 33/ds Downstream
- 36/sg Staff gauge
- 51/gp Gas probe
- 53/ge Gas extraction well
- 55/gc Gas condensate
- 57/sv Soil venting wells (includes both soil vapor extraction and bioventing, includes both extraction and unsaturated zone gas phase injection wells installed in soil or fill, but not refuse)
- 58/gm Gas sample monitoring point
- 61/ij Injection well (injection of liquids not gases)
- 62/as In situ air sparging well (injection well to inject gases into the aquifer)
- 63/uv Unterdruck Verdampfer Brunnen (UVB) wells (sparging wells where the gases remain in the well and are not injected into the aquifer)
- 64/le Groundwater and light non-aqueous phase liquid (LNAPL) extraction wells
- 65/de Groundwater and dense non-aqueous phase liquid (DNAPL) extraction wells
- 66/ve Vacuum enhanced groundwater extraction wells
- 67/vi Vacuum enhanced groundwater and LNAPL extraction wells
- 68/vd Vacuum enhanced groundwater and DNAPL extraction wells
- 71/dw Subtitle D water table observation well (see 11/mw)
- 72/dp Subtitle D piezometer (see 12/pz)
- 80/mc Municipal water supply well: cities, villages, and sanitary districts
- 81/oc Community-other-than-municipal water supply well: mobile home parks, apartments, subdivisions, and condominium complexes
- 82/nn Noncommunity-Nontransient water supply well (schools, day care centers, and industries) A Noncommunity water system that regularly serves at least 25 of the same persons over 6 months per year
- 83/tn Noncommunity-Transient water supply well (motels, restaurants, parks, taverns, churches, and campgrounds) A Noncommunity water system that serves at least 25 people at least 60 days of the year

99/ot Other

Well Status: The status of the well using the following codes:

- A - Actively monitored well
- I - Inactive well (existing well not currently being monitored)
- P - Permanently abandoned well
- N - Potable well not currently used for consumption but actively monitored

Enf. Stds.: Check this box only if enforcement standards apply at this well.

Enforcement standards apply at any well beyond the Design Management Zone or the property boundary of the facility or at a water supply well. For spills, enforcement standards apply at every point at which groundwater is monitored. (For more information, see s. NR 140.22, Wis. Adm. Code.)

Gradient: The location of the well in the groundwater flow system relative to the disposal site, spill, etc. Use one of the four letters designated below:

U = up gradient D = down gradient
S = side gradient N = not known

Distance to Waste: Distance Well Is From Waste/Source Boundary. Enter distance in feet from the monitoring well to the edge of a facility waste storage structure, e.g., from the edge of a wastewater lagoon or the approved waste fill boundary for a landfill. For a contaminant source which is not a facility, e.g., a spill, enter the distance the well is from the contaminant source.

Location Coordinates Are: State Plane Coordinate System, an established location system for Wisconsin or Local grid system, established for the site and submitted to the Department.

Grid Origin Location: Give the location in Latitude and Longitude in degrees, minutes and seconds using 1927 North American Datum or State Plane Coordinates. If State Plane Coordinates are used, circle the appropriate letter for south, central or north zone.

The Grid Origin can be determined by surveying or by Global Positioning System (GPS) (with processing to be accurate within 1 foot and reported with precision to hundredths (0.01) of a second). An acceptable method for providing this information without surveying is to locate the Grid Origin on a USGS 7.5 minute quadrangle map. The Location of the Grid Origin can then be interpolated (estimated) using standard cartographic techniques. If the Grid Origin location is estimated, check the estimated box.

Remarks: Add any remarks to help clarify items listed above; e.g. MW-17 was abandoned on 1/24/90 and replaced by MW-17R; LHW-1 and LHW-2 are leachate head wells.

Appendix B

Monitoring Well Purging and Sampling Guidance

U.S. ENVIRONMENTAL PROTECTION AGENCY REGION I

LOW STRESS (low flow) PURGING AND SAMPLING PROCEDURE FOR THE COLLECTION OF GROUNDWATER SAMPLES FROM MONITORING WELLS

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Region 1 Low-Stress
(Low-Flow) SOP
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USE OF TERMS

Equipment blank: The equipment blank shall include the pump and the pump's tubing. If tubing is dedicated to the well, the equipment blank needs only to include the pump in subsequent sampling rounds. If the pump and tubing are dedicated to the well, the equipment blank is collected prior to its placement in the well. If the pump and tubing will be used to sample multiple wells, the equipment blank is normally collected after sampling from contaminated wells and not after background wells.

Field duplicates: Field duplicates are collected to determine precision of the sampling procedure. For this procedure, collect duplicate for each analyte group in consecutive order (VOC original, VOC duplicate, SVOC original, SVOC duplicate, etc.).

Indicator field parameters: This SOP uses field measurements of turbidity, dissolved oxygen, specific conductance, temperature, pH, and oxidation/reduction potential (ORP) as indicators of when purging operations are sufficient and sample collection may begin.

Matrix Spike/Matrix Spike Duplicates: Used by the laboratory in its quality assurance program. Consult the laboratory for the sample volume to be collected.

Potentiometric Surface: The level to which water rises in a tightly cased well constructed in a confined aquifer. In an unconfined aquifer, the potentiometric surface is the water table.

QAPP: Quality Assurance Project Plan

SAP: Sampling and Analysis Plan

SOP: Standard operating procedure

Stabilization: A condition that is achieved when all indicator field parameter measurements are sufficiently stable (as described in the "Monitoring Indicator Field Parameters" section) to allow sample collection to begin.

Temperature blank: A temperature blank is added to each sample cooler. The blank is measured upon receipt at the laboratory to assess whether the samples were properly cooled during transit.

Trip blank (VOCs): Trip blank is a sample of analyte-free water taken to the sampling site and returned to the laboratory. The trip blanks (one pair) are added to each sample cooler that contains VOC samples.

SCOPE & APPLICATION

The goal of this groundwater sampling procedure is to collect water samples that reflect the total mobile organic and inorganic loads (dissolved and colloidal sized fractions) transported through the subsurface under ambient flow conditions, with minimal physical and chemical alterations from sampling operations. This standard operating procedure (SOP) for collecting groundwater samples will help ensure that the project's data quality objectives (DQOs) are met under certain low-flow conditions.

The SOP emphasizes the need to minimize hydraulic stress at the well-aquifer interface by maintaining low water-level drawdowns, and by using low pumping rates during purging and sampling operations. Indicator field parameters (e.g., dissolved oxygen, pH, etc.) are monitored during purging in order to determine when sample collection may begin. Samples properly collected using this SOP are suitable for analysis of groundwater contaminants (volatile and semi-volatile organic analytes, dissolved gases, pesticides, PCBs, metals and other inorganics), or naturally occurring analytes. This SOP is based on Puls, and Barcelona (1996).

This procedure is designed for monitoring wells with an inside diameter (1.5-inches or greater) that can accommodate a positive lift pump with a screen length or open interval ten feet or less and with a water level above the top of the screen or open interval (Hereafter, the "screen or open interval" will be referred to only as "screen interval"). This SOP is not applicable to other well-sampling conditions.

While the use of dedicated sampling equipment is not mandatory, dedicated pumps and tubing can reduce sampling costs significantly by streamlining sampling activities and thereby reducing the overall field costs.

The goal of this procedure is to emphasize the need for consistency in deploying and operating equipment while purging and sampling monitoring wells during each sampling event. This will help to minimize sampling variability.

This procedure describes a general framework for groundwater sampling. Other site specific information (hydrogeological context, conceptual site model (CSM), DQOs, etc.) coupled with systematic planning must be added to the procedure in order to develop an appropriate site specific SAP/QAPP. In addition, the site specific SAP/QAPP must identify the specific equipment that will be used to collect the groundwater samples.

This procedure does not address the collection of water or free product samples from wells containing free phase LNAPLs and/or DNAPLs (light or dense non-aqueous phase

liquids). For this type of situation, the reader may wish to check: Cohen, and Mercer (1993) or other pertinent documents.

This SOP is to be used when collecting groundwater samples from monitoring wells at all Superfund, Federal Facility and RCRA sites in Region 1 under the conditions described herein. Request for modification of this SOP, in order to better address specific situations at individual wells, must include adequate technical justification for proposed changes. All changes and modifications must be approved and included in a revised SAP/QAPP before implementation in field.

BACKGROUND FOR IMPLEMENTATION

It is expected that the monitoring well screen has been properly located (both laterally and vertically) to intercept existing contaminant plume(s) or along flow paths of potential contaminant migration. Problems with inappropriate monitoring well placement or faulty/improper well installation cannot be overcome by even the best water sampling procedures. This SOP presumes that the analytes of interest are moving (or will potentially move) primarily through the more permeable zones intercepted by the screen interval.

Proper well construction, development, and operation and maintenance cannot be overemphasized. The use of installation techniques that are appropriate to the hydrogeologic setting of the site often prevent "problem well" situations from occurring. During well development, or redevelopment, tests should be conducted to determine the hydraulic characteristics of the monitoring well. The data can then be used to set the purging/sampling rate, and provide a baseline for evaluating changes in well performance and the potential need for well rehabilitation. Note: if this installation data or well history (construction and sampling) is not available or discoverable, for all wells to be sampled, efforts to build a sampling history should commence with the next sampling event.

The pump intake should be located within the screen interval and at a depth that will remain under water at all times. It is recommended that the intake depth and pumping rate remain the same for all sampling events. The mid-point or the lowest historical midpoint of the saturated screen length is often used as the location of the pump intake. For new wells, or for wells without pump intake depth information, the site's SAP/QAPP must provide clear reasons and instructions on how the pump intake depth(s) will be selected, and reason(s) for the depth(s) selected. If the depths to top and bottom of the well screen are not known, the SAP/QAPP will need to describe how the sampling depth will be determined and how the data can be used.

Stabilization of indicator field parameters is used to indicate that conditions are suitable for sampling to begin. Achievement of turbidity levels of less than 5 NTU, and stable drawdowns of less than 0.3 feet, while desirable, are not mandatory. Sample collection

may still take place provided the indicator field parameter criteria in this procedure are met. If after 2 hours of purging indicator field parameters have not stabilized, one of three optional courses of action may be taken: a) continue purging until stabilization is achieved, b) discontinue purging, do not collect any samples, and record in log book that stabilization could not be achieved (documentation must describe attempts to achieve stabilization), c) discontinue purging, collect samples and provide full explanation of attempts to achieve stabilization (note: there is a risk that the analytical data obtained, especially metals and strongly hydrophobic organic analytes, may reflect a sampling bias and therefore, the data may not meet the data quality objectives of the sampling event).

It is recommended that low-flow sampling be conducted when the air temperature is above 32°F (0°C). If the procedure is used below 32°F, special precautions will need to be taken to prevent the groundwater from freezing in the equipment. Because sampling during freezing temperatures may adversely impact the data quality objectives, the need for water sample collection during months when these conditions are likely to occur should be evaluated during site planning and special sampling measures may need to be developed. Ice formation in the flow-through-cell will cause the monitoring probes to act erratically. A transparent flow-through-cell needs to be used to observe if ice is forming in the cell. If ice starts to form on the other pieces of the sampling equipment, additional problems may occur.

HEALTH & SAFETY

When working on-site, comply with all applicable OSHA requirements and the site's health/safety procedures. All proper personal protection clothing and equipment are to be worn. Some samples may contain biological and chemical hazards. These samples should be handled with suitable protection to skin, eyes, etc.

CAUTIONS

The following cautions need to be considered when planning to collect groundwater samples when the below conditions occur.

If the groundwater degasses during purging of the monitoring well, dissolved gases and VOCs will be lost. When this happens, the groundwater data for dissolved gases (e.g., methane, ethene, ethane, dissolved oxygen, etc.) and VOCs will need to be qualified. Some conditions that can promote degassing are the use of a vacuum pump (e.g., peristaltic pumps), changes in aperture along the sampling tubing, and squeezing/pinching the pump's tubing which results in a pressure change.

When collecting the samples for dissolved gases and VOCs analyses, avoid aerating the groundwater in the pump's tubing. This can cause loss of the dissolved gases and VOCs in

the groundwater. Having the pump's tubing completely filled prior to sampling will avoid this problem when using a centrifugal pump or peristaltic pump.

Direct sun light and hot ambient air temperatures may cause the groundwater in the tubing and flow-through-cell to heat up. This may cause the groundwater to degas which will result in loss of VOCs and dissolved gases. When sampling under these conditions, the sampler will need to shade the equipment from the sunlight (e.g., umbrella, tent, etc.). If possible, sampling on hot days, or during the hottest time of the day, should be avoided. The tubing exiting the monitoring well should be kept as short as possible to avoid the sun light or ambient air from heating up the groundwater.

Thermal currents in the monitoring well may cause vertical mixing of water in the well bore. When the air temperature is colder than the groundwater temperature, it can cool the top of the water column. Colder water which is denser than warm water sinks to the bottom of the well and the warmer water at the bottom of the well rises, setting up a convection cell. "During low-flow sampling, the pumped water may be a mixture of convecting water from within the well casing and aquifer water moving inward through the screen. This mixing of water during low-flow sampling can substantially increase equilibration times, can cause false stabilization of indicator parameters, can give false indication of redox state, and can provide biological data that are not representative of the aquifer conditions" (Vroblesky 2007).

Failure to calibrate or perform proper maintenance on the sampling equipment and measurement instruments (e.g., dissolved oxygen meter, etc.) can result in faulty data being collected.

Interferences may result from using contaminated equipment, cleaning materials, sample containers, or uncontrolled ambient/surrounding air conditions (e.g., truck/vehicle exhaust nearby).

Cross contamination problems can be eliminated or minimized through the use of dedicated sampling equipment and/or proper planning to avoid ambient air interferences. Note that the use of dedicated sampling equipment can also significantly reduce the time needed to complete each sampling event, will promote consistency in the sampling, and may reduce sampling bias by having the pump's intake at a constant depth.

Clean and decontaminate all sampling equipment prior to use. All sampling equipment needs to be routinely checked to be free from contaminants and equipment blanks collected to ensure that the equipment is free of contaminants. Check the previous equipment blank data for the site (if they exist) to determine if the previous cleaning procedure removed the contaminants. If contaminants were detected and they are a concern, then a more vigorous cleaning procedure will be needed.

PERSONNEL QUALIFICATIONS

All field samplers working at sites containing hazardous waste must meet the requirements of the OSHA regulations. OSHA regulations may require the sampler to take the 40 hour OSHA health and safety training course and a refresher course prior to engaging in any field activities, depending upon the site and field conditions.

The field samplers must be trained prior to the use of the sampling equipment, field instruments, and procedures. Training is to be conducted by an experienced sampler before initiating any sampling procedure.

The entire sampling team needs to read, and be familiar with, the site Health and Safety Plan, all relevant SOPs, and SAP/QAPP (and the most recent amendments) before going onsite for the sampling event. It is recommended that the field sampling leader attest to the understanding of these site documents and that it is recorded.

EQUIPMENT AND SUPPLIES

A. Informational materials for sampling event

A copy of the current Health and Safety Plan, SAP/QAPP, monitoring well construction data, location map(s), field data from last sampling event, manuals for sampling, and the monitoring instruments' operation, maintenance, and calibration manuals should be brought to the site.

B. Well keys.

C. Extraction device

Adjustable rate, submersible pumps (e.g., centrifugal, bladder, etc.) which are constructed of stainless steel or Teflon are preferred. Note: if extraction devices constructed of other materials are to be used, adequate information must be provided to show that the substituted materials do not leach contaminants nor cause interferences to the analytical procedures to be used. Acceptance of these materials must be obtained before the sampling event.

If bladder pumps are selected for the collection of VOCs and dissolved gases, the pump setting should be set so that one pulse will deliver a water volume that is sufficient to fill a 40 mL VOC vial. This is not mandatory, but is considered a "best practice". For the proper operation, the bladder pump will need a minimum amount of water above the pump; consult the manufacturer for the recommended submergence. The pump's recommended submergence value should be determined during the planning stage, since it may influence well construction and placement of dedicated pumps where water-level fluctuations are significant.

Adjustable rate, peristaltic pumps (suction) are to be used with caution when collecting samples for VOCs and dissolved gases (e.g., methane, carbon dioxide, etc.) analyses. Additional information on the use of peristaltic pumps can be found in Appendix A. If peristaltic pumps are used, the inside diameter of the rotor head tubing needs to match the inside diameter of the tubing installed in the monitoring well.

Inertial pumping devices (motor driven or manual) are not recommended. These devices frequently cause greater disturbance during purging and sampling, and are less easily controlled than submersible pumps (potentially increasing turbidity and sampling variability, etc.). This can lead to sampling results that are adversely affected by purging and sampling operations, and a higher degree of data variability.

D. Tubing

Teflon or Teflon-lined polyethylene tubing are preferred when sampling is to include VOCs, SVOCs, pesticides, PCBs and inorganics. Note: if tubing constructed of other materials is to be used, adequate information must be provided to show that the substituted materials do not leach contaminants nor cause interferences to the analytical procedures to be used. Acceptance of these materials must be obtained before the sampling event.

PVC, polypropylene or polyethylene tubing may be used when collecting samples for metal and other inorganics analyses.

The use of 1/4 inch or 3/8 inch (inside diameter) tubing is recommended. This will help ensure that the tubing remains liquid filled when operating at very low pumping rates when using centrifugal and peristaltic pumps.

Silastic tubing should be used for the section around the rotor head of a peristaltic pump. It should be less than a foot in length. The inside diameter of the tubing used at the pump rotor head must be the same as the inside diameter of tubing placed in the well. A tubing connector is used to connect the pump rotor head tubing to the well tubing. Alternatively, the two pieces of tubing can be connected to each other by placing the one end of the tubing inside the end of the other tubing. The tubing must not be reused.

E. The water level measuring device

Electronic "tape", pressure transducer, water level sounder/level indicator, etc. should be capable of measuring to 0.01 foot accuracy. Recording pressure transducers, mounted above the pump, are especially helpful in tracking water levels during pumping operations, but their use must include check measurements with a water level "tape" at the start and end of each sampling event.

F. Flow measurement supplies

Graduated cylinder (size according to flow rate) and stopwatch usually will suffice.

Large graduated bucket used to record total water purged from the well.

G. Interface probe

To be used to check on the presence of free phase liquids (LNAPL, or DNAPL) before purging begins (as needed).

H. Power source (generator, nitrogen tank, battery, etc.)

When a gasoline generator is used, locate it downwind and at least 30 feet from the well so that the exhaust fumes do not contaminate samples.

I. Indicator field parameter monitoring instruments

Use of a multi-parameter instrument capable of measuring pH, oxidation/reduction potential (ORP), dissolved oxygen (DO), specific conductance, temperature, and coupled with a flow-through-cell is required when measuring all indicator field parameters, except turbidity. Turbidity is collected using a separate instrument. Record equipment/instrument identification (manufacturer, and model number).

Transparent, small volume flow-through-cells (e.g., 250 mLs or less) are preferred. This allows observation of air bubbles and sediment buildup in the cell, which can interfere with the operation of the monitoring instrument probes, to be easily detected. A small volume cell facilitates rapid turnover of water in the cell between measurements of the indicator field parameters.

It is recommended to use a flow-through-cell and monitoring probes from the same manufacturer and model to avoid incompatibility between the probes and flow-through-cell.

Turbidity samples are collected before the flow-through-cell. A "T" connector coupled with a valve is connected between the pump's tubing and flow-through-cell. When a turbidity measurement is required, the valve is opened to allow the groundwater to flow into a container. The valve is closed and the container sample is then placed in the turbidimeter.

Standards are necessary to perform field calibration of instruments. A minimum of two standards are needed to bracket the instrument measurement range for all parameters except ORP which use a Zobell solution as a standard. For dissolved oxygen, a wet sponge used for the 100% saturation and a zero dissolved oxygen solution are used for the calibration.

Barometer (used in the calibration of the Dissolved Oxygen probe) and the conversion formula to convert the barometric pressure into the units of measure used by the Dissolved Oxygen meter are needed.

J. Decontamination supplies

Includes (for example) non-phosphate detergent, distilled/deionized water, isopropyl alcohol, etc.

K. Record keeping supplies

Logbook(s), well purging forms, chain-of-custody forms, field instrument calibration forms, etc.

L. Sample bottles

M. Sample preservation supplies (as required by the analytical methods)

N. Sample tags or labels

O. PID or FID instrument

If appropriate, to detect VOCs for health and safety purposes, and provide qualitative field evaluations.

P. Miscellaneous Equipment

Equipment to keep the sampling apparatus shaded in the summer (e.g., umbrella) and from freezing in the winter. If the pump's tubing is allowed to heat up in the warm weather, the cold groundwater may degas as it is warmed in the tubing.

EQUIPMENT/INSTRUMENT CALIBRATION

Prior to the sampling event, perform maintenance checks on the equipment and instruments according to the manufacturer's manual and/or applicable SOP. This will ensure that the equipment/instruments are working properly before they are used in the field.

Prior to sampling, the monitoring instruments must be calibrated and the calibration documented. The instruments are calibrated using U.S. Environmental Protection Agency Region 1 *Calibration of Field Instruments (temperature, pH, dissolved oxygen, conductivity/specific conductance, oxidation/reduction [ORP], and turbidity)*, January 19, 2010, or latest version or from one of the methods listed in 40CFR136, 40CFR141 and SW-846.

The instruments shall be calibrated at the beginning of each day. If the field measurement falls outside the calibration range, the instrument must be re-calibrated so that all measurements fall within the calibration range. At the end of each day, a calibration check is performed to verify that instruments remained in calibration throughout the day. This check is performed while the instrument is in measurement mode, not calibration mode. If the field instruments are being used to monitor the natural attenuation parameters, then a calibration check at mid-day is highly recommended to ensure that the instruments did not drift out of calibration. Note: during the day if the instrument reads zero or a negative number for dissolved oxygen, pH, specific conductance, or turbidity (negative value only), this indicates that the instrument drifted out of calibration or the instrument is malfunctioning. If this situation occurs the data from this instrument will need to be qualified or rejected.

PRELIMINARY SITE ACTIVITIES (as applicable)

Check the well for security (damage, evidence of tampering, missing lock, etc.) and record pertinent observations (include photograph as warranted).

If needed lay out sheet of clean polyethylene for monitoring and sampling equipment, unless equipment is elevated above the ground (e.g., on a table, etc.).

Remove well cap and if appropriate measure VOCs at the rim of the well with a PID or FID instrument and record reading in field logbook or on the well purge form.

If the well casing does not have an established reference point (usually a V-cut or indelible mark in the well casing), make one. Describe its location and record the date of the mark in the logbook (consider a photographic record as well). All water level measurements must be recorded relative to this reference point (and the altitude of this point should be determined using techniques that are appropriate to site's DQOs).

If water-table or potentiometric surface map(s) are to be constructed for the sampling event, perform synoptic water level measurement round (in the shortest possible time) before any purging and sampling activities begin. If possible, measure water level depth (to 0.01 ft.) and total well depth (to 0.1 ft.) the day before sampling begins, in order to allow for re-settlement of any particulates in the water column. This is especially important for those wells that have not been recently sampled because sediment buildup in the well may require the well to be redeveloped. If measurement of total well depth is not made the day before, it should be measured after sampling of the well is complete. All measurements must be taken from the established referenced point. Care should be taken to minimize water column disturbance.

Check newly constructed wells for the presence of LNAPLs or DNAPLs before the initial sampling round. If none are encountered, subsequent check measurements with an interface probe may not be necessary unless analytical data or field analysis signal a worsening situation. This SOP cannot be used in the presence of LNAPLs or DNAPLs. If NAPLs are present, the project team must decide upon an alternate sampling method. All project modifications must be approved and documented prior to implementation.

If available check intake depth and drawdown information from previous sampling event(s) for each well. Duplicate, to the extent practicable, the intake depth and extraction rate (use final pump dial setting information) from previous event(s). If changes are made in the intake depth or extraction rate(s) used during previous sampling event(s), for either portable or dedicated extraction devices, record new values, and explain reasons for the changes in the field logbook.

PURGING AND SAMPLING PROCEDURE

Purging and sampling wells in order of increasing chemical concentrations (known or anticipated) are preferred.

The use of dedicated pumps is recommended to minimize artificial mobilization and entrainment of particulates each time the well is sampled. Note that the use of dedicated sampling equipment can also significantly reduce the time needed to complete each

sampling event, will promote consistency in the sampling, and may reduce sampling bias by having the pump's intake at a constant depth.

A. Initial Water Level

Measure the water level in the well before installing the pump if a non-dedicated pump is being used. The initial water level is recorded on the purge form or in the field logbook.

B. Install Pump

Lower pump, safety cable, tubing and electrical lines slowly (to minimize disturbance) into the well to the appropriate depth (may not be the mid-point of the screen/open interval). The Sampling and Analysis Plan/Quality Assurance Project Plan should specify the sampling depth (used previously), or provide criteria for selection of intake depth for each new well. If possible keep the pump intake at least two feet above the bottom of the well, to minimize mobilization of particulates present in the bottom of the well.

Pump tubing lengths, above the top of well casing should be kept as short as possible to minimize heating the groundwater in the tubing by exposure to sun light and ambient air temperatures. Heating may cause the groundwater to degas, which is unacceptable for the collection of samples for VOC and dissolved gases analyses.

C. Measure Water Level

Before starting pump, measure water level. Install recording pressure transducer, if used to track drawdowns, to initialize starting condition.

D. Purge Well

From the time the pump starts purging and until the time the samples are collected, the purged water is discharged into a graduated bucket to determine the total volume of groundwater purged. This information is recorded on the purge form or in the field logbook.

Start the pump at low speed and slowly increase the speed until discharge occurs. Check water level. Check equipment for water leaks and if present fix or replace the affected equipment. Try to match pumping rate used during previous sampling event(s). Otherwise, adjust pump speed until there is little or no water level drawdown. If the minimal drawdown that can be achieved exceeds 0.3 feet, but remains stable, continue purging.

Monitor and record the water level and pumping rate every five minutes (or as appropriate) during purging. Record any pumping rate adjustments (both time and flow rate). Pumping rates should, as needed, be reduced to the minimum capabilities of the pump to ensure stabilization of the water level. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During pump start-up, drawdown may exceed the 0.3 feet target and then "recover" somewhat as pump flow adjustments are made. Purge volume calculations should utilize stabilized drawdown value, not the initial drawdown. If the initial water level is above the top of the screen do not allow the water level to fall into the well screen. The final purge volume must be greater than the stabilized drawdown volume plus the pump's tubing volume. If the drawdown has exceeded 0.3 feet and stabilizes, calculate the volume of water between the initial water level and the stabilized water level. Add the volume of the water which occupies the pump's tubing to this calculation. This combined volume of water needs to be purged from the well after the water level has stabilized before samples are collected.

Avoid the use of constriction devices on the tubing to decrease the flow rate because the constrictor will cause a pressure difference in the water column. This will cause the groundwater to degas and result in a loss of VOCs and dissolved gasses in the groundwater samples.

Note: the flow rate used to achieve a stable pumping level should remain constant while monitoring the indicator parameters for stabilization and while collecting the samples.

Wells with low recharge rates may require the use of special pumps capable of attaining very low pumping rates (e.g., bladder, peristaltic), and/or the use of dedicated equipment. For new monitoring wells, or wells where the following situation has not occurred before, if the recovery rate to the well is less than 50 mL/min., or the well is being essentially dewatered during purging, the well should be sampled as soon as the water level has recovered sufficiently to collect the volume needed for all anticipated samples. The project manager or field team leader will need to make the decision when samples should be collected, how the sample is to be collected, and the reasons recorded on the purge form or in the field logbook. A water level measurement needs to be performed and recorded before samples are collected. If the project manager decides to collect the samples using the pump, it is best during this recovery period that the pump intake tubing not be removed, since this will aggravate any turbidity problems. Samples in this specific situation may be collected without stabilization of indicator field parameters. Note that field conditions and efforts to overcome problematic situations must be recorded in order to support field decisions to deviate from normal procedures described in this SOP. If this type of problematic situation persists in a well, then water sample collection should be changed to a passive or no-purge method, if consistent with the site's DQOs, or have a new well installed.

E. Monitor Indicator Field Parameters

After the water level has stabilized, connect the "T" connector with a valve and the flow-through-cell to monitor the indicator field parameters. If excessive turbidity is anticipated or encountered with the pump startup, the well may be purged for a while without connecting up the flow-through-cell, in order to minimize particulate buildup in the cell (This is a judgment call made by the sampler). Water level drawdown measurements should be made as usual. If possible, the pump may be installed the day before purging to allow particulates that were disturbed during pump insertion to settle.

During well purging, monitor indicator field parameters (turbidity, temperature, specific conductance, pH, ORP, DO) at a frequency of five minute intervals or greater. The pump's flow rate must be able to "turn over" at least one flow-through-cell volume between measurements (for a 250 mL flow-through-cell with a flow rate of 50 mLs/min., the monitoring frequency would be every five minutes; for a 500 mL flow-through-cell it would be every ten minutes). If the cell volume cannot be replaced in the five minute interval, then the time between measurements must be increased accordingly. Note: during the early phase of purging emphasis should be put on minimizing and stabilizing pumping stress, and recording those adjustments followed by stabilization of indicator parameters. Purging is considered complete and sampling may begin when all the above indicator field parameters have stabilized. Stabilization is considered to be achieved when three consecutive readings are within the following limits:

Turbidity (10% for values greater than 5 NTU; if three Turbidity values are less than 5 NTU, consider the values as stabilized),

Dissolved Oxygen (10% for values greater than 0.5 mg/L, if three Dissolved Oxygen values are less than 0.5 mg/L, consider the values as stabilized),

Specific Conductance (3%),

Temperature (3%),

pH (± 0.1 unit),

Oxidation/Reduction Potential (± 10 millivolts).

All measurements, except turbidity, must be obtained using a flow-through-cell. Samples for turbidity measurements are obtained before water enters the flow-through-cell. Transparent flow-through-cells are preferred, because they allow field personnel to watch for particulate build-up within the cell. This build-up may affect indicator field parameter values measured within the cell. If the cell needs to be cleaned during purging operations, continue pumping and disconnect cell for cleaning, then reconnect after cleaning and continue monitoring activities. Record start and stop times and give a brief description of cleaning activities.

The flow-through-cell must be designed in a way that prevents gas bubble entrapment in the cell. Placing the flow-through-cell at a 45 degree angle with the port facing upward can help remove bubbles from the flow-through-cell (see Appendix B Low-Flow Setup Diagram). All during the measurement process, the flow-through-cell must remain free of any gas bubbles. Otherwise, the monitoring probes may act erratically. When the pump is turned off or cycling on/off (when using a bladder pump), water in the cell must not drain out. Monitoring probes must remain submerged in water at all times.

F. Collect Water Samples

When samples are collected for laboratory analyses, the pump's tubing is disconnected from the "T" connector with a valve and the flow-through-cell. The samples are collected directly from the pump's tubing. Samples must not be collected from the flow-through-cell or from the "T" connector with a valve.

VOC samples are normally collected first and directly into pre-preserved sample containers. However, this may not be the case for all sampling locations; the SAP/QAPP should list the order in which the samples are to be collected based on the project's objective(s). Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

If the pump's flow rate is too high to collect the VOC/dissolved gases samples, collect the other samples first. Lower the pump's flow rate to a reasonable rate and collect the VOC/dissolved gases samples and record the new flow rate.

During purging and sampling, the centrifugal/peristaltic pump tubing must remain filled with water to avoid aeration of the groundwater. It is recommended that 1/4 inch or 3/8 inch (inside diameter) tubing be used to help insure that the sample tubing remains water filled. If the pump tubing is not completely filled to the sampling point, use the following procedure to collect samples: collect non-VOC/dissolved gases samples first, then increase flow rate slightly until the water completely fills the tubing, collect the VOC/dissolved gases samples, and record new drawdown depth and flow rate.

For bladder pumps that will be used to collect VOC or dissolved gas samples, it is recommended that the pump be set to deliver long pulses of water so that one pulse will fill a 40 mL VOC vial.

Use pre-preserved sample containers or add preservative, as required by analytical methods, to the samples immediately after they are collected. Check the analytical methods (e.g. EPA SW-846, 40 CFR 136, water supply, etc.) for additional information on preservation.

If determination of filtered metal concentrations is a sampling objective, collect filtered water samples using the same low flow procedures. The use of an in-line filter (transparent housing preferred) is required, and the filter size (0.45 μm is commonly used) should be based on the sampling objective. Pre-rinse the filter with groundwater prior to sample collection. Make sure the filter is free of air bubbles before samples are collected. Preserve the filtered water sample immediately. Note: filtered water samples are not an acceptable substitute for unfiltered samples when the monitoring objective is to obtain chemical concentrations of total mobile contaminants in groundwater for human health or ecological risk calculations.

Label each sample as collected. Samples requiring cooling will be placed into a cooler with ice or refrigerant for delivery to the laboratory. Metal samples after acidification to a pH less than 2 do not need to be cooled.

G. Post Sampling Activities

If a recording pressure transducer is used to track drawdown, re-measure water level with tape.

After collection of samples, the pump tubing may be dedicated to the well for re-sampling (by hanging the tubing inside the well), decontaminated, or properly discarded.

Before securing the well, measure and record the well depth (to 0.1 ft.), if not measured the day before purging began. Note: measurement of total well depth annually is usually sufficient after the initial low stress sampling event. However, a greater frequency may be needed if the well has a "silting" problem or if confirmation of well identity is needed.

Secure the well.

DECONTAMINATION

Decontaminate sampling equipment prior to use in the first well and then following sampling of each well. Pumps should not be removed between purging and sampling operations. The pump, tubing, support cable and electrical wires which were in contact with the well should be decontaminated by one of the procedures listed below.

The use of dedicated pumps and tubing will reduce the amount of time spent on decontamination of the equipment. If dedicated pumps and tubing are used, only the initial sampling event will require decontamination of the pump and tubing.

Note if the previous equipment blank data showed that contaminant(s) were present after using the below procedure or the one described in the SAP/QAPP, a more vigorous procedure may be needed.

Procedure 1

Decontaminating solutions can be pumped from either buckets or short PVC casing sections through the pump and tubing. The pump may be disassembled and flushed with the decontaminating solutions. It is recommended that detergent and alcohol be used sparingly in the decontamination process and water flushing steps be extended to ensure that any sediment trapped in the pump is removed. The pump exterior and electrical wires must be rinsed with the decontaminating solutions, as well. The procedure is as follows:

Flush the equipment/pump with potable water.

Flush with non-phosphate detergent solution. If the solution is recycled, the solution must be changed periodically.

Flush with potable or distilled/deionized water to remove all of the detergent solution. If the water is recycled, the water must be changed periodically.

Optional - flush with isopropyl alcohol (pesticide grade; must be free of ketones {e.g., acetone}) or with methanol. This step may be required if the well is highly contaminated or if the equipment blank data from the previous sampling event show that the level of contaminants is significant.

Flush with distilled/deionized water. This step must remove all traces of alcohol (if used) from the equipment. The final water rinse must not be recycled.

Procedure 2

Steam clean the outside of the submersible pump.

Pump hot potable water from the steam cleaner through the inside of the pump. This can be accomplished by placing the pump inside a three or four inch diameter PVC pipe with end cap. Hot water from the steam cleaner jet will be directed inside the PVC pipe and the pump exterior will be cleaned. The hot water from the steam cleaner will then be pumped from the PVC pipe through the pump and collected into another container. Note: additives or solutions should not be added to the steam cleaner.

Pump non-phosphate detergent solution through the inside of the pump. If the solution is recycled, the solution must be changed periodically.

Pump potable water through the inside of the pump to remove all of the detergent solution. If the solution is recycled, the solution must be changed periodically.

Pump distilled/deionized water through the pump. The final water rinse must not be recycled.

FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not compromised the quality of the groundwater samples. All field quality control samples must be prepared the same as regular investigation samples with regard to sample volume, containers, and preservation. Quality control samples include field duplicates, equipment blanks, matrix spike/matrix spike duplicates, trip blanks (VOCs), and temperature blanks.

FIELD LOGBOOK

A field log shall be kept to document all groundwater field monitoring activities (see Appendix C, example table), and record the following for each well:

Site name, municipality, state.

Well identifier, latitude-longitude or state grid coordinates.

Measuring point description (e.g., north side of PVC pipe).

Well depth, and measurement technique.

Well screen length.

Pump depth.

Static water level depth, date, time and measurement technique.

Presence and thickness of immiscible liquid (NAPL) layers and detection method.

Pumping rate, drawdown, indicator parameters values, calculated or measured total volume pumped, and clock time of each set of measurements.

Type of tubing used and its length.

Type of pump used.

Clock time of start and end of purging and sampling activity.

Types of sample bottles used and sample identification numbers.

Preservatives used.

Parameters requested for analyses.

Field observations during sampling event.

Name of sample collector(s).

Weather conditions, including approximate ambient air temperature.

QA/QC data for field instruments.

Any problems encountered should be highlighted.

Description of all sampling/monitoring equipment used, including trade names, model number, instrument identification number, diameters, material composition, etc.

DATA REPORT

Data reports are to include laboratory analytical results, QA/QC information, field indicator parameters measured during purging, field instrument calibration information, and whatever other field logbook information is needed to allow for a full evaluation of data usability.

Note: the use of trade, product, or firm names in this sampling procedure is for descriptive purposes only and does not constitute endorsement by the U.S. EPA.

REFERENCES

Cohen, R.M. and J.W. Mercer, 1993, *DNAPL Site Evaluation*; C.K. Smoley (CRC Press), Boca Raton, Florida.

Robert W. Puls and Michael J. Barcelona, *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures*, April 1996 (EPA/540/S-95/504).

U.S. Environmental Protection Agency, 1992, *RCRA Ground-Water Monitoring: Draft Technical Guidance*; Washington, DC (EPA/530-R-93-001).

U.S. Environmental Protection Agency, 1987, *A Compendium of Superfund Field Operations Methods*; Washington, DC (EPA/540/P-87/001).

U.S. Environmental Protection Agency, Region 1, *Calibration of Field Instruments (temperature, pH, dissolved oxygen, conductivity/specific conductance, oxidation/reduction [ORP], and turbidity)*, January 19, 2010 or latest version.

U.S. Environmental Protection Agency, EPA SW-846.

U.S. Environmental Protection Agency, 40 CFR 136.

U.S. Environmental Protection Agency, 40 CFR 141.

Vroblesky, Don A., Clifton C. Casey, and Mark A. Lowery, Summer 2007, Influence of Dissolved Oxygen Convection on Well Sampling, *Ground Water Monitoring & Remediation* 27, no. 3: 49-58.

APPENDIX A PERISTALTIC PUMPS

Before selecting a peristaltic pump to collect groundwater samples for VOCs and/or dissolved gases (e.g., methane, carbon dioxide, etc.) consideration should be given to the following:

- The decision of whether or not to use a peristaltic pump is dependent on the intended use of the data.
- If the additional sampling error that may be introduced by this device is NOT of concern for the VOC/dissolved gases data's intended use, then this device may be acceptable.
- If minor differences in the groundwater concentrations could effect the decision, such as to continue or terminate groundwater cleanup or whether the cleanup goals have been reached, then this device should NOT be used for VOC/dissolved gases sampling. In these cases, centrifugal or bladder pumps are a better choice for more accurate results.

EPA and USGS have documented their concerns with the use of the peristaltic pumps to collect water sample in the below documents.

- "Suction Pumps are not recommended because they may cause degassing, pH modification, and loss of volatile compounds" *A Compendium of Superfund Field Operations Methods*, EPA/540/P-87/001, December 1987.
- "The agency does not recommend the use of peristaltic pumps to sample ground water particularly for volatile organic analytes" *RCRA Ground-Water Monitoring Draft Technical Guidance*, EPA Office of Solid Waste, November 1992.
- "The peristaltic pump is limited to shallow applications and can cause degassing resulting in alteration of pH, alkalinity, and volatiles loss", *Low-flow (Minimal drawdown) Ground-Water Sampling Procedures*, by Robert Puls & Michael Barcelona, April 1996, EPA/540/S-95/504.
- "Suction-lift pumps, such as peristaltic pumps, can operate at a very low pumping rate; however, using negative pressure to lift the sample can result in the loss of volatile analytes", USGS Book 9 Techniques of Water-Resources Investigation, Chapter A4. (Version 2.0, 9/2006).

APPENDIX B

SUMMARY OF SAMPLING INSTRUCTIONS

These instructions are for using an adjustable rate, submersible pump or a peristaltic pump with the pump's intake placed at the midpoint of a 10 foot or less well screen or an open interval. The water level in the monitoring well is above the top of the well screen or open interval, the ambient temperature is above 32°F, and the equipment is not dedicated. Field instruments are already calibrated. The equipment is setup according to the diagram at the end of these instructions.

1. Review well installation information. Record well depth, length of screen or open interval, and depth to top of the well screen. Determine the pump's intake depth (e.g., mid-point of screen/open interval).
2. On the day of sampling, check security of the well casing, perform any safety checks needed for the site, lay out a sheet of polyethylene around the well (if necessary), and setup the equipment. If necessary a canopy or an equivalent item can be setup to shade the pump's tubing and flow-through-cell from the sun light to prevent the sun light from heating the groundwater.
3. Check well casing for a reference mark. If missing, make a reference mark. Measure the water level (initial) to 0.01 ft. and record this information.
4. Install the pump's intake to the appropriate depth (e.g., midpoint) of the well screen or open interval. Do not turn-on the pump at this time.
5. Measure water level and record this information.
6. Turn-on the pump and discharge the groundwater into a graduated waste bucket. Slowly increase the flow rate until the water level starts to drop. Reduce the flow rate slightly so the water level stabilizes. Record the pump's settings. Calculate the flow rate using a graduated container and a stop watch. Record the flow rate. Do not let the water level drop below the top of the well screen.

If the groundwater is highly turbid or colored, continue to discharge the water into the bucket until the water clears (visual observation); this usually takes a few minutes. The turbid or colored water is usually from the well being disturbed during the pump installation. If the water does not clear, then you need to make a choice whether to continue purging the well (hoping that it will clear after a reasonable time) or continue to

the next step. Note, it is sometimes helpful to install the pump the day before the sampling event so that the disturbed materials in the well can settle out.

If the water level drops to the top of the well screen during the purging of the well, stop purging the well, and do the following:

Wait for the well to recharge to a sufficient volume so samples can be collected. This may take awhile (pump maybe removed from well, if turbidity is not a problem). The project manager will need to make the decision when samples should be collected and the reasons recorded in the site's log book. A water level measurement needs to be performed and recorded before samples are collected. When samples are being collected, the water level must not drop below the top of the screen or open interval. Collect the samples from the pump's tubing. Always collect the VOCs and dissolved gases samples first. Normally, the samples requiring a small volume are collected before the large volume samples are collected just in case there is not sufficient water in the well to fill all the sample containers. All samples must be collected, preserved, and stored according to the analytical method. Remove the pump from the well and decontaminate the sampling equipment.

If the water level has dropped 0.3 feet or less from the initial water level (water level measure before the pump was installed); proceed to Step 7. If the water level has dropped more than 0.3 feet, calculate the volume of water between the initial water level and the stabilized water level. Add the volume of the water which occupies the pump's tubing to this calculation. This combined volume of water needs to be purged from the well after the water level has stabilized before samples are collected.

7. Attach the pump's tubing to the "T" connector with a valve (or a three-way stop cock). The pump's tubing from the well casing to the "T" connector must be as short as possible to prevent the groundwater in the tubing from heating up from the sun light or from the ambient air. Attach a short piece of tubing to the other end of the "T" connector to serve as a sampling port for the turbidity samples. Attach the remaining end of the "T" connector to a short piece of tubing and connect the tubing to the flow-through-cell bottom port. To the top port, attach a small piece of tubing to direct the water into a calibrated waste bucket. Fill the cell with the groundwater and remove all gas bubbles from the cell. Position the flow-through-cell in such a way that if gas bubbles enter the cell they can easily exit the cell. If the ports are on the same side of the cell and the cell is cylindrical shape, the cell can be placed at a 45-degree angle with the ports facing upwards; this position should keep any gas bubbles entering the cell away from the monitoring probes and allow the gas bubbles to exit the cell easily (see Low-Flow Setup Diagram). Note,

make sure there are no gas bubbles caught in the probes' protective guard; you may need to shake the cell to remove these bubbles.

8. Turn-on the monitoring probes and turbidity meter.

9. Record the temperature, pH, dissolved oxygen, specific conductance, and oxidation/reduction potential measurements. Open the valve on the "T" connector to collect a sample for the turbidity measurement, close the valve, do the measurement, and record this measurement. Calculate the pump's flow rate from the water exiting the flow-through-cell using a graduated container and a stop watch, and record the measurement. Measure and record the water level. Check flow-through-cell for gas bubbles and sediment; if present, remove them.

10. Repeat Step 9 every 5 minutes or as appropriate until monitoring parameters stabilized. Note at least one flow-through-cell volume must be exchanged between readings. If not, the time interval between readings will need to be increased. Stabilization is achieved when three consecutive measurements are within the following limits:

Turbidity (10% for values greater than 5 NTUs; if three Turbidity values are less than 5 NTUs, consider the values as stabilized),

Dissolved Oxygen (10% for values greater than 0.5 mg/L, if three Dissolved Oxygen values are less than 0.5 mg/L, consider the values as stabilized),

Specific Conductance (3%),

Temperature (3%),

pH (± 0.1 unit),

Oxidation/Reduction Potential (± 10 millivolts).

If these stabilization requirements do not stabilize in a reasonable time, the probes may have been coated from the materials in the groundwater, from a buildup of sediment in the flow-through-cell, or a gas bubble is lodged in the probe. The cell and the probes will need to be cleaned. Turn-off the probes (not the pump), disconnect the cell from the "T" connector and continue to purge the well. Disassemble the cell, remove the sediment, and clean the probes according to the manufacturer's instructions. Reassemble the cell and connect the cell to the "T" connector. Remove all gas bubbles from the cell, turn-on the probes, and continue the measurements. Record that the time the cell was cleaned.

11. When it is time to collect the groundwater samples, turn-off the monitoring probes, and disconnect the pump's tubing from the "T" connector. If you are using a centrifugal or peristaltic pump check the pump's tubing to determine if the tubing is completely filled with water (no air space).

All samples must be collected and preserved according to the analytical method. VOCs and dissolved gases samples are normally collected first and directly into pre-preserved sample containers. However, this may not be the case for all sampling locations; the SAP/QAPP should list the order in which the samples are to be collected based on the project's objective(s). Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

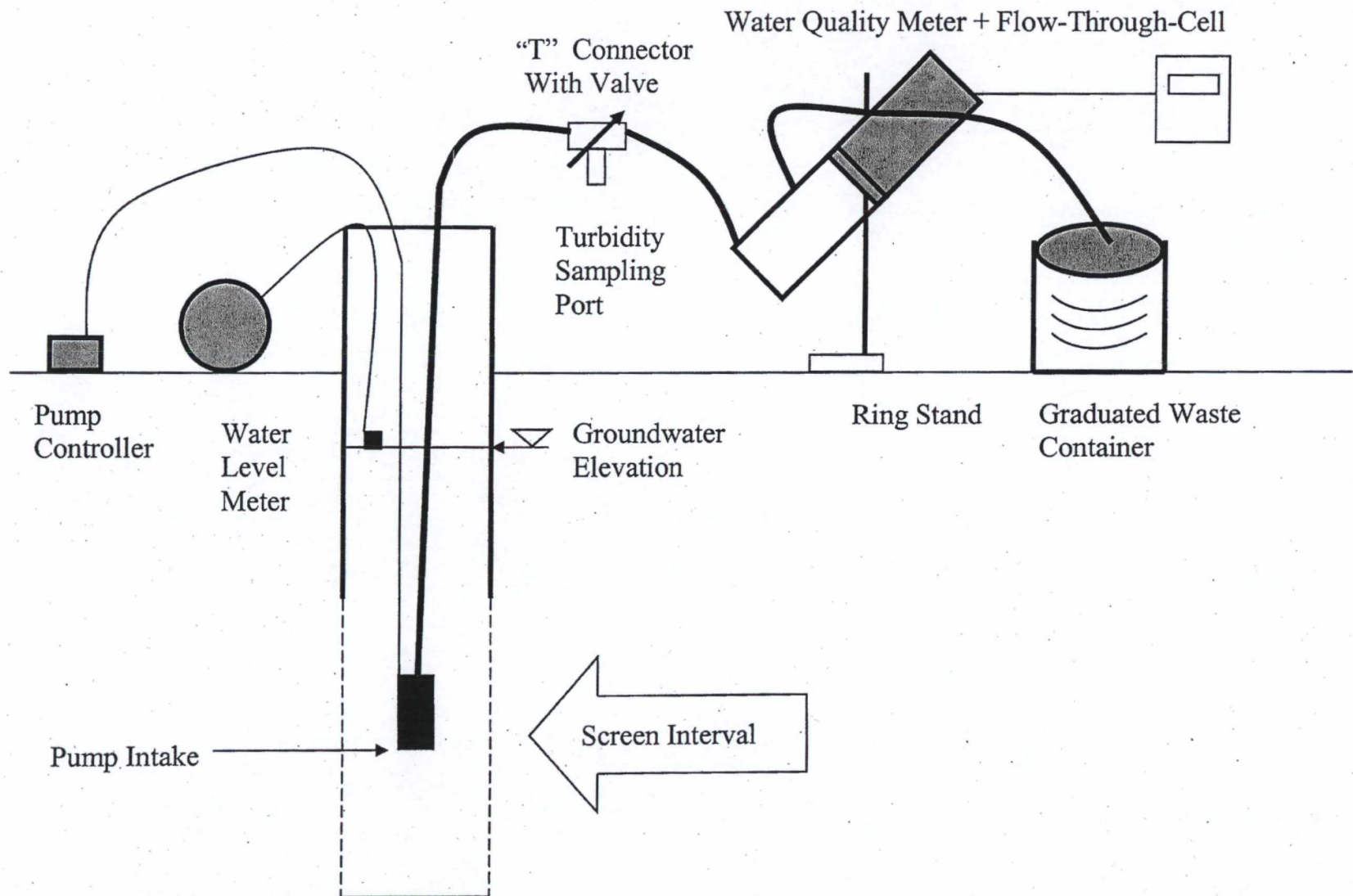
If the pump's tubing is not completely filled with water and the samples are being collected for VOCs and/or dissolved gases analyses using a centrifugal or peristaltic pump, do the following:

All samples must be collected and preserved according to the analytical method. The VOCs and the dissolved gases (e.g., methane, ethane, ethene, and carbon dioxide) samples are collected last. When it becomes time to collect these samples increase the pump's flow rate until the tubing is completely filled. Collect the samples and record the new flow rate.

12. Store the samples according to the analytical method.

13. Record the total purged volume (graduated waste bucket). Remove the pump from the well and decontaminate the sampling equipment.

Low-Flow Setup Diagram



EXAMPLE (Minimum Requirements)
WELL PURGING-FIELD WATER QUALITY MEASUREMENTS FORM

[illegible]

Stabilization Criteria

3%

3%

 $\pm 0.1 \pm 10 \text{ mv}$

10%

10%

1. Pump dial setting (for example: hertz, cycles/min, etc).
2. μ Siemens per cm (same as μ mhos/cm) at 25°C.
3. Oxidation reduction potential (ORP)

We appreciate your interest in Microbial Insights' CENSUS® analysis. CENSUS®, a molecular biological tool employing quantitative polymerase chain reaction (qPCR), allows site managers to cost-effectively detect and quantify specific microorganisms or functional genes deemed critical for successful bioremediation. Currently, Microbial Insights offers over 30 different CENSUS® assays for assessing biodegradation of a broad spectrum of contaminants ranging from petroleum hydrocarbons to chlorinated solvents.

We would like to take this opportunity to provide some background information for specific CENSUS® assays along with the Cost Proposal requested.

- **Dehalococcoides (qDHC):** The only bacterial group isolated to date that is capable of complete reductive dechlorination of PCE and TCE to ethene. In fact, the presence of *Dehalococcoides* spp. has been associated with the full dechlorination to ethene at sites across North America and Europe (1).

Elevated *Dehalococcoides* concentrations ($\geq 10^4$ *Dehalococcoides* cells/mL) are associated with complete reductive dechlorination, but the range of chlorinated ethenes metabolized and cometabolized varies by species and strains within the *Dehalococcoides* genus. Since the accumulation of daughter products termed a DCE or vinyl chloride "stall" can be a concern, Microbial Insights offers a group of CENSUS® assays for quantification of *Dehalococcoides* functional genes encoding reductive dehalogenases to more definitively confirm the potential for reductive dechlorination of TCE, *cis*-DCE, and most importantly, vinyl chloride.

- **TCE Reductase (*tceA*):** The *tceA* gene encodes the enzyme responsible for reductive dechlorination of TCE to *cis*-DCE in some strains of *Dehalococcoides*. Although the *tceA* gene is not universally distributed among all strains of *Dehalococcoides* and the absence of *tceA* does not preclude the potential for reductive dechlorination of TCE in the field, detection of the *tceA* gene provides an additional line of evidence indicating the potential for dechlorination of TCE.
- **Vinyl Chloride Reductase (*bvcA*):** The *bvcA* gene encodes the vinyl chloride reductase enzyme responsible for reductive dechlorination of vinyl chloride to ethene by *Dehalococcoides* sp. str. BAV1 (2). While reports of detection frequency vary in the literature, *bvcA* is the only vinyl chloride reductase gene detected at some sites (3) and has been demonstrated as the most abundant and actively expressed vinyl chloride reductase gene in PCE column studies (4). In an internal study, ethene production was observed in 80% of the samples in which the *Dehalococcoides* population was greater than or equal to 10^4 cells/mL. The *bvcA* vinyl chloride reductase gene was detected in over 50% of these samples thus confirming the importance of the *bvcA* vinyl chloride reductase in the complete reductive dechlorination.
- **Vinyl Chloride Reductase (*vcrA*):** The *vcrA* gene encodes the vinyl chloride reductase enzyme responsible for reductive dechlorination of *cis*-DCE and vinyl chloride by *Dehalococcoides* sp. strain VS (5). As with the *bvcA* vinyl chloride reductase gene, detection of the *vcrA* gene is associated with ethene production in internal studies (67%) and vinyl chloride reduction in independent studies (3, 5).

Microbial Insights is a molecular microbiology laboratory – we do not offer commercial bioaugmentation cultures or remediation products. We believe that each client deserves unbiased results that are both accurate and precise. Furthermore, we recognize the value of every client. No matter how large or small your project, we are committed to serving you at each step in the process, from assay selection through data interpretation.

We look forward to working with you.

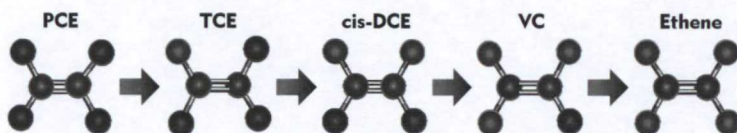
References

1. Hendrickson, E.R., J. Payne, R.M. Young, M.G. Starr, M.P. Perry, S. Fahnestock, D.E. Ellis, and R.C. Eversole. 2002. Molecular analysis of *Dehalococcoides* 16S ribosomal DNA from chloroethene-contaminated sites throughout North America and Europe. *Applied and Environmental Microbiology* 68(2): 485-495.
2. Krajmalnik-Brown, R., T. Hölscher, I. N. Thomson, F. M. Saunders, K. M. Ritalahti, and F. E. Löffler. 2004. Genetic identification of a putative vinyl chloride reductase in *Dehalococcoides* sp. strain BAV1. *Applied and Environmental Microbiology* 70:6347–6351.
3. van der Zaan, B., F. Hannes, N. Hoekstra, H. Rijnaarts, W.M. de Vos, H. Smidt, and J. Gerritse. 2010. Correlation of *Dehalococcoides* 16S rRNA and chloroethene-reductive dehalogenase genes with geochemical conditions in chloroethene-contaminated groundwater. *Applied and Environmental Microbiology* 76(3):843-850.
4. Behrens, S., M.F., Azizian, P.J. McMurdie, A. Sabalowsky, M.E. Dolan, L. Semprini, and A.M. Spormann. 2008. Monitoring abundance and expression of *Dehalococcoides* species chloroethene-reductive dehalogenases in a tetrachloroethene-dechlorinating flow column. *Applied and Environmental Microbiology* 74(18):5695-5703.
5. Müller, J.A., B.M. Rosner, G. von Avendroth, G. Meshulam-Simon, P.L. McCarty, and A.M. Spormann. 2004. Molecular identification of the catabolic vinyl chloride reductase from *Dehalococcoides* sp. strain VS and its environmental distribution. *Applied and Environmental Microbiology* 70(8): 4880-4888.



Detect and quantify *Dehalococcoides* and other bacteria capable of reductive dechlorination

Under anaerobic conditions, certain bacteria can use chlorinated ethenes (PCE, TCE, DCE, and VC) as electron acceptors in a process called reductive dechlorination. The net result is the sequential dechlorination of PCE and TCE through daughter products DCE and VC to non-toxic ethene, which volatilizes or can be further metabolized.



Successful reductive dechlorination can be hindered by a few site-specific factors that cannot be evaluated with chemical and geochemical tests including:

- a lack of a key dechlorinating bacteria including *Dehalococcoides* spp., the only known bacteria that completely dechlorinates PCE and TCE to non-toxic ethene
- reasons for incomplete dechlorination and the accumulation of daughter products (DCE stall)

CENSUS® provides the most direct avenue to investigate the potentials and limitations to implementing corrective action plan decisions and to target a variety of organisms involved in the reductive dechlorination pathway.

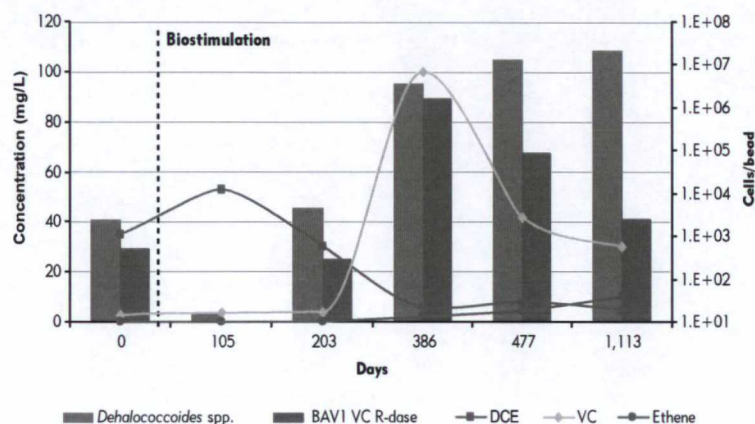
Target	Code	Contaminants	Environmental Relevance / Data Interpretation
<i>Dehalococcoides</i>	qDHC	PCE, TCE, DCE, VC	Only known group of bacteria capable of complete dechlorination of PCE and/or TCE to ethene Absence of <i>Dehalococcoides</i> suggests dechlorination of DCE and VC is improbable and accumulation of daughter products is likely The presence of <i>Dehalococcoides</i> even in low copy numbers indicates the potential for complete reductive dechlorination Higher copy numbers and the presence of daughter products suggest that dechlorination may be occurring
<i>Dehalococcoides</i> Functional Genes	qTCE qVC	TCE, VC	Functional genes encoding reductive dehalogenases for TCE and VC Presence of TCE reductase indicates the ability to reduce TCE to DCE and VC Presence of VC reductase indicates the potential for reductive dechlorination of VC to ethene Absence of VC reductase suggests that VC may accumulate
<i>Dehalobacter</i>	qDHB	PCA, TCA, PCE, TCE	Capable of dechlorination of PCE and TCE to cis-DCE Converts TCA, a common co-contaminant at PCE/TCA-impacted sites to chloroethane
<i>Desulfuromonas</i>	qDSM	PCE, TCE	Capable of dechlorination of PCE and TCE to cis-DCE using acetate as an electron donor
<i>Desulfitobacterium</i>	qDSB	PCE, TCE	Capable of dechlorination of PCE and TCE to cis-DCE
Total bacteria	qEBAC		Index of total bacterial biomass Domain level
Methanogens	qMGN		Methanogens utilize hydrogen and carbon dioxide to produce methane Compete with dechlorinating bacteria for available hydrogen
Iron and Sulfate Reducing Bacteria	qSRB/IRB		Targets delta-Proteobacteria Index of iron and sulfate reducing bacteria including <i>Geobacter</i> , <i>Pelobacter</i> , <i>Desulfovibrio</i> , and <i>Desulfuromonas</i>

When combined with chemical and geochemical groundwater monitoring programs, CENSUS® results provide a valuable tool to determine:

- the feasibility of bioremediation of PCE/TCE under MNA conditions
- the ability of bioremediation approaches to meet overall treatment goals

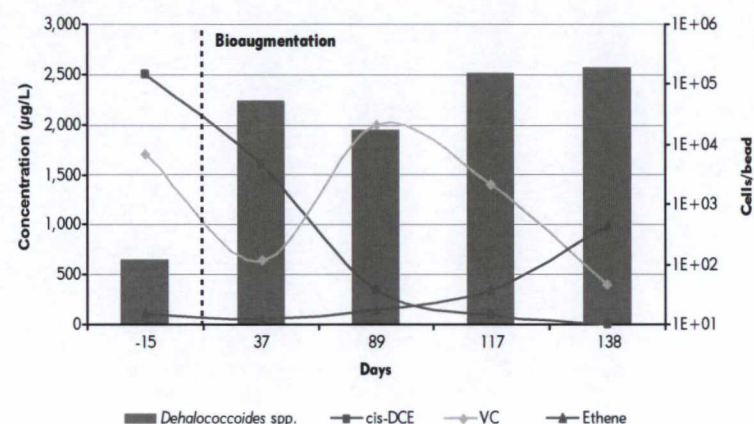
- the effectiveness of enhanced bioremediation (e.g. sodium lactate or vegetable oil injection) to promote reductive dechlorination

Biostimulation



- The relatively low *Dehalococcoides* (DHC) population (10^3 cells/bead) and the accumulation of the daughter product DCE indicated that monitored natural attenuation (MNA) would not meet remediation goals in an acceptable timeframe.
- Following HRC® injection to promote reductive dechlorination, the DHC population increased to 10^6 – 10^7 cells/bead with a corresponding decrease in DCE.
- Vinyl chloride (VC) concentrations temporarily increased due to the reductive dechlorination of DCE.
- As indicated by the high number of DHC and VC reductase genes however, microorganisms capable of reductive dechlorination of VC were present.
- VC concentrations decreased after the initial spike with a corresponding increase in ethene.

Bioaugmentation



- Initially, the *Dehalococcoides* (DHC) population was low (10^2 cells/bead) and daughter products had accumulated suggesting MNA would not provide complete reductive dechlorination of PCE.
- Following bioaugmentation, the DHC population increased by 3 orders of magnitude with a corresponding decrease in DCE.
- Vinyl chloride (VC) concentrations temporarily increased due to the reductive dechlorination of DCE.
- The continued detection of DHC, however, indicated the potential for complete reductive dechlorination.
- VC concentrations decreased with a corresponding increase in ethene production.

mi BIO-TRAP®

Catch Remediation in the Act... **Trap It!**

ADVANCED DIAGNOSTIC SAMPLERS

What are Bio-Trap® Samplers?

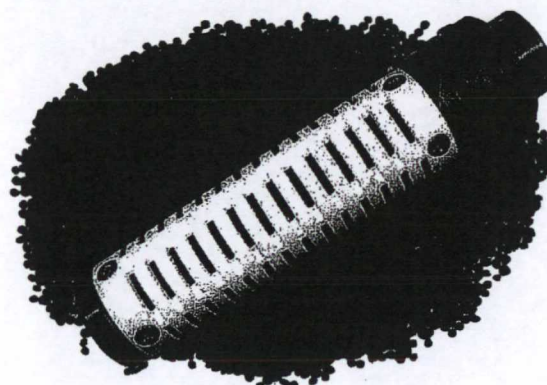
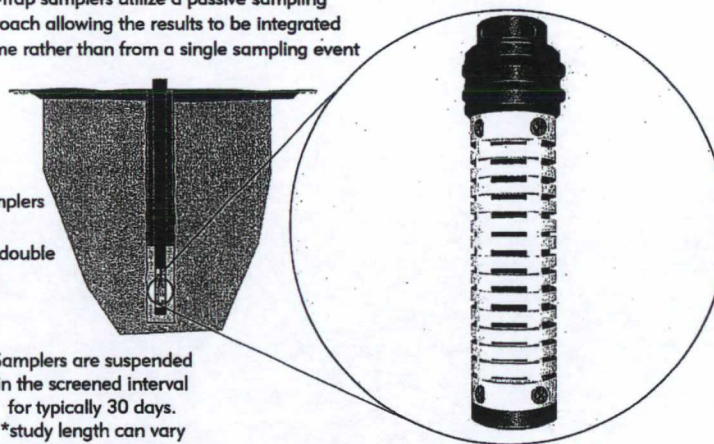
Bio-Trap® Samplers are passive sampling tools that collect microbes over time for the purpose of better understanding biodegradation potential. The key to the Bio-Trap® approach is a unique sampling matrix, Bio-Sep® beads. The beads are 2-3 mm in diameter and are engineered from a composite of Nomex® and powdered activated carbon (PAC). When a Bio-Trap® Sampler is deployed in a monitoring well, the Bio-Sep® beads adsorb contaminants and nutrients present in the aquifer essentially becoming an *in situ* microcosm with an incredibly large surface area (~600 m²/g) which is colonized by subsurface microorganisms. Once recovered from a monitoring well (30-60 days after deployment), DNA, RNA, or PLFA can be extracted from the beads for CENSUS® or PLFA assays to evaluate the microbial community.

A modern approach to microbial sampling

Bio-Trap samplers utilize a passive sampling approach allowing the results to be integrated over time rather than from a single sampling event

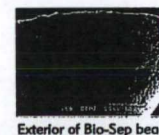
Multiple Bio-Trap samplers can be isolated from one another using a double seal cap assembly

Samplers are suspended in the screened interval for typically 30 days.
*study length can vary depending on objectives



Sampling Matrix: Bio-Sep® Beads

A key to this sampling approach is the use of Bio-Sep® beads as the sampling matrix. The unique properties of these beads allow them to mimic environmental conditions very well.



Exterior of Bio-Sep bead



Interior of Bio-Sep bead



Lactate amended Bio-Sep® bead

Bio-Sep® beads provide a large surface area within the bead for microbial attachment. Most microbes prefer to be attached to a surface rather than be free floating.

Fishin' for microbes! "Baited" Bio-Trap® samplers can be used to evaluate the microbial response to a wide range of amendments (electron donors and acceptors, etc.).

*see reverse for more details

Samplers can be analyzed using a wide variety of analyses including:

Molecular Biological Tools

- CENSUS® (qPCR)
- PLFA
- DGGE
- SIP

Chemical Analysis

Geochemical Parameters
And more!

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What types of samplers are available?

Bio-Trap samplers are available in a wide variety of configurations that can be tailored to answer your site-specific questions.

Standard: Basic Bio-Trap® Samplers in the simplest terms are a replacement for collecting groundwater samples using a conventional approach. Most microbes prefer to be attached to a surface rather than free floating and this passive sampler provides a large surface area for the microbes to colonize. Results generated using this approach have been shown to minimize the variability associated with traditional sampling approaches. Bio-Traps biofilms have also been shown to directly reflect spatial and temporal changes in aquifer microbial community structure plume which could not be determined from groundwater analysis. Standard Bio-Trap® Samplers are primarily used during site characterization and routine monitoring activities to:

- Quantify specific microbes or contaminant degrading bacteria (e.g. *Dehalococcoides* spp.)
- Evaluate monitored natural attenuation (MNA)
- Compare microbial populations from different sampling points
- Monitor shifts within microbial communities following biostimulation

Standard Bio-Trap® Samplers are designed for microbial analyses using a variety of molecular biological tools but can also be configured for some chemical and geochemical analyses.



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Baited: As the name suggests, Bio-Trap® Samplers can be "baited" with various amendments or compounds to answer site-specific questions. In the past, project managers have been forced to turn to laboratory microcosms or small-scale pilot studies to evaluate bioremediation as a treatment alternative. While microcosm experiments with native site materials can show biodegradation in the laboratory, duplication of *in situ* conditions is difficult and the results may not extrapolate to the field. Pilot studies are performed on site but are often prohibitively expensive as an investigative tool. Baited Bio-Trap® Samplers are designed to create discrete *in situ* microcosms that can be used to:

- Evaluate monitored natural attenuation versus enhanced bioremediation
- Compare effectiveness of different amendments (e.g. HRC®, EOS®, sodium lactate, molasses, etc.) designed to stimulate bioremediation
- Prove that biodegradation is occurring (¹³C-labeled compounds - Stable Isotope Probing)
- Estimate relative rates of degradation for a specific contaminant (i.e. MTBE, TBA etc.)
- Address specific questions such as:
 - Is benzene being degraded at my site?
 - Will sulfate amendments stimulate bioremediation?
 - Will sodium lactate increase the concentration of known dechlorinating bacteria?

Baited Bio-Trap® Samplers can be amended with a number of compounds including:

- Sodium acetate
- Sodium lactate
- Potassium lactate
- HRC®
- Molasses
- Vegetable oil
- EOS®
- Sodium phosphate
- Sulfate
- Nitrate
- Ammonium chloride
- Elemental sulfur
- Calcium carbonate
- Iron (III)
- ¹³C-labeled contaminants
 - Benzene
 - Toluene
 - Xylene
 - MTBE
 - TBA
 - Chlorobenzene
 - TCE
 - DCE
 - VC
- Fluorinated surrogates for tracing chlorinated compounds
 - TCE
 - DCE
- And more!

Targets available for a wide range of organisms including:

- Dechlorinating Bacteria
 - Dehalococcoides* spp.
 - Desulfuromonas* spp.
 - Dehalobacter* spp.
 - Desulfotobacterium* spp.
 - And more!

Bacterial groups involved in remedial processes

- Methanogens
- Sulfate/iron reducing bacteria
- Geobacter* spp.
- Methane oxidizing bacteria
- Propane oxidizing bacteria
- Denitrifying bacteria
- Ammonia oxidizers
- BTEX utilizing bacteria
- MTBE utilizing PM1
- Acetogens
- Total bacteria
- Fungi
- Anaerobic ammonia oxidizing bacteria (Anammox)
- And more

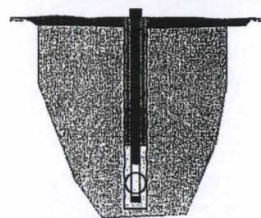
How does CENSUS® work?

CENSUS® is based on a technique called quantitative polymerase chain reaction (qPCR) whereby many copies of a specific gene are generated. As each gene copy is made, a fluorescent marker is released, measured, and used to quantify the number of target genes present in the sample. The gene copied during the process (target gene) is determined by short segments of DNA called "primers" which are added to the reaction mixture. In essence, qPCR is like a copy machine with a counter. The "primers" select which pages (target gene) of the

book (DNA) are copied and the counter keeps a running total of how many pages were copied (number of target genes in the sample).

Traditionally, culture-based methods such as plate counts or most probable number (MPN) analyses have been used to estimate bacterial populations in environmental samples. However, cultivation based approaches detect less than 10% of the targeted bacterial group thus severely underestimating the total population.

Sample Collection



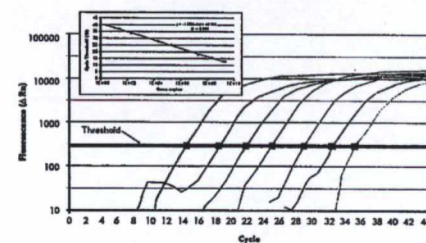
Groundwater, soil, or Bio-Trap® Sampler collected and shipped overnight on ice (4°C)

DNA Extraction



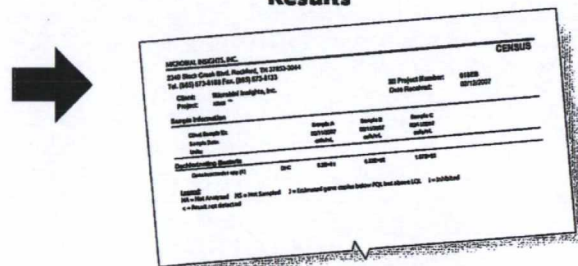
DNA is extracted from samples upon arrival

Amplification



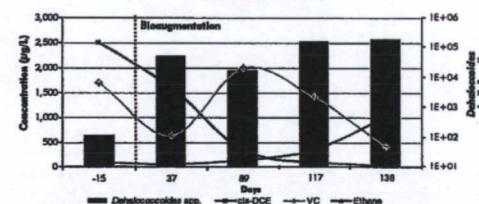
Quantitative Real-Time PCR is used to detect and quantify targets of interest (i.e. *Dehalococcoides* spp.)

Results



Results are emailed to project contact

Assessment



Results are integrated with other site parameters to evaluate site management decisions

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mi CENSUS®

MOLECULAR BIOLOGICAL TOOL

Rapidly detect and quantify specific microbial populations and processes

CENSUS® allows site managers to cost effectively quantify targeted members of the microbial community deemed critical for site remediation. At a site impacted by chlorinated solvents like PCE or TCE for example, quantification of *Dehalococcoides* spp. (DHC), a key dechlorinating bacteria, permits project managers to address the following:

- Directly evaluate the feasibility of monitored natural attenuation
- Evaluate the efficacy of enhanced bioremediation approaches
- Assess the need for bioaugmentation

Currently, Microbial Insights offers over 30 targets for a wide variety of functions ranging from reductive dechlorination of chlorinated solvents to BTEX and MTBE biodegradation that can provide direct evidence of the biological processes occurring at your site.

CENSUS® Advantages:

- **Accurate** — Direct analysis of sample removes the need to grow the bacteria thus eliminating biases associated with more traditional based approaches (i.e. plate counts).
- **Specific** — Target either the specific bacterial group (e.g. *Dehalococcoides* spp.) or a specific gene encoding a desired function (e.g. reductive dechlorination).
- **Rapid** — Results are available within days (7–10 standard TAT) * Rush service available.
- **Sensitivity** — Practical Detection Limits (PDL) are as low as 100 cells per sample with a dynamic range over seven orders of magnitude.

Targets available for a wide range of pollutants including:

Chlorinated Compounds:

- PCE, TCE, DCE, VC
- TCA, DCA
- PCP
- Perchlorate

And more!

Petroleum Hydrocarbons:

- BTEX
- MTBE
- Diesel
- Naphthalene
- Alkanes



Approaches include:

CENSUS® is offered in a variety of formats to meet the objectives of your particular project. Please choose from the following:

CENSUS® — Are organisms present that have the potential to degrade...?

Our standard DNA based approach provides quantification of bacteria with the genetic potential to degrade a particular contaminant.

CENSUS®-Expression — Are organisms actively expressing a desired function?

RNA as opposed to DNA is extracted and used to quantify metabolically active bacteria of interest expressing the desired function.

CENSUS®-Store — What were the baseline results before treatment?

Collect those valuable points in time and store them for potential future analysis. Allows the collection of more data points at a lower cost. Samples can be stored and processed even years down the road.

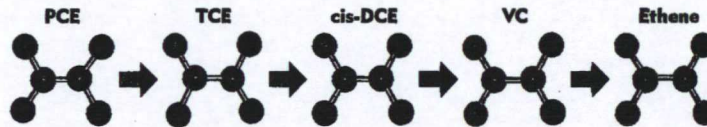
Need the ability to quantify a unique population or function? MI can develop custom **CENSUS®** targets for your contaminant of concern. For more information, please call us at (865) 573-8188.

mi CENSUS®

MOLECULAR BIOLOGICAL TOOL

Detect and quantify *Dehalococcoides* and other bacteria capable of reductive dechlorination

Under anaerobic conditions, certain bacteria can use chlorinated ethenes (PCE, TCE, DCE, and VC) as electron acceptors in a process called reductive dechlorination. The net result is the sequential dechlorination of PCE and TCE through daughter products DCE and VC to non-toxic ethene, which volatilizes or can be further metabolized.



Successful reductive dechlorination can be hindered by a few site-specific factors that cannot be evaluated with chemical and geochemical tests including:

- a lack of a key dechlorinating bacteria including *Dehalococcoides* spp., the only known bacteria that completely dechlorinates PCE and TCE to non-toxic ethene
- reasons for incomplete dechlorination and the accumulation of daughter products (DCE stall)

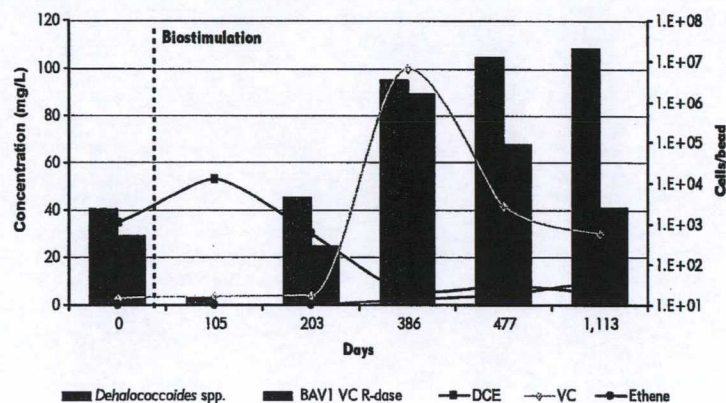
CENSUS® provides the most direct avenue to investigate the potentials and limitations to implementing corrective action plan decisions and to target a variety of organisms involved in the reductive dechlorination pathway.

Target	Code	Contaminants	Environmental Relevance / Data Interpretation
<i>Dehalococcoides</i>	qDHC	PCE, TCE, DCE, VC	Only known group of bacteria capable of complete dechlorination of PCE and/or TCE to ethene Absence of <i>Dehalococcoides</i> suggests dechlorination of DCE and VC is improbable and accumulation of daughter products is likely The presence of <i>Dehalococcoides</i> even in low copy numbers indicates the potential for complete reductive dechlorination Higher copy numbers and the presence of daughter products suggest that dechlorination may be occurring
<i>Dehalococcoides</i> Functional Genes	qTCE qVC	TCE, VC	Functional genes encoding reductive dehalogenases for TCE and VC Presence of TCE reductase indicates the ability to reduce TCE to DCE and VC Presence of VC reductase indicates the potential for reductive dechlorination of VC to ethene Absence of VC reductase suggests that VC may accumulate
<i>Dehalobacter</i>	qDHB	PCA, TCA, PCE, TCE	Capable of dechlorination of PCE and TCE to cis-DCE Converts TCA, a common co-contaminant at PCE/TCA-impacted sites to chloroethane
<i>Desulfuromonas</i>	qDSM	PCE, TCE	Capable of dechlorination of PCE and TCE to cis-DCE using acetate as an electron donor
<i>Desulfotobacterium</i>	qDSB	PCE, TCE	Capable of dechlorination of PCE and TCE to cis-DCE
Total bacteria	qEBAC		Index of total bacterial biomass Domain level
Methanogens	qMGN		Methanogens utilize hydrogen and carbon dioxide to produce methane Compete with dechlorinating bacteria for available hydrogen
Iron and Sulfate Reducing Bacteria	qSRB/IRB		Targets delta-Proteobacteria Index of iron and sulfate reducing bacteria including <i>Geobacter</i> , <i>Pelobacter</i> , <i>Desulfovibrio</i> , and <i>Desulfuromonas</i>

When combined with chemical and geochemical groundwater monitoring programs, CENSUS® results provide a valuable tool to determine:

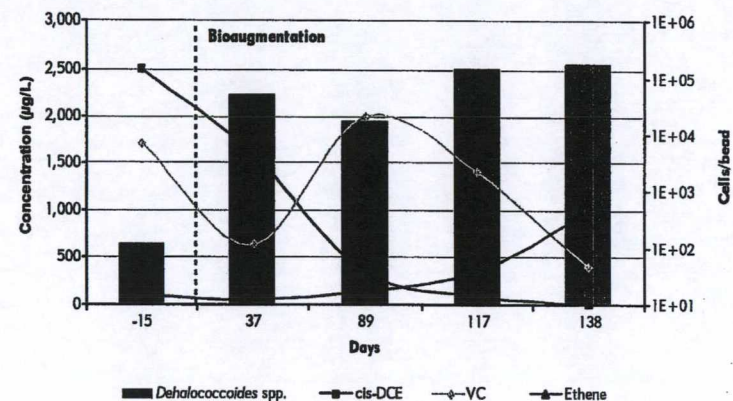
- the feasibility of bioremediation of PCE/TCE under MNA conditions
- the ability of bioremediation approaches to meet overall treatment goals
- the effectiveness of enhanced bioremediation (e.g. sodium lactate or vegetable oil injection) to promote reductive dechlorination

Biostimulation



- The relatively low *Dehalococcoides* (DHC) population (10^3 cells/bead) and the accumulation of the daughter product DCE indicated that monitored natural attenuation (MNA) would not meet remediation goals in an acceptable timeframe.
- Following HRC® injection to promote reductive dechlorination, the DHC population increased to 10^6 – 10^7 cells/bead with a corresponding decrease in DCE.
- Vinyl chloride (VC) concentrations temporarily increased due to the reductive dechlorination of DCE.
- As indicated by the high number of DHC and VC reductase genes however, microorganisms capable of reductive dechlorination of VC were present.
- VC concentrations decreased after the initial spike with a corresponding increase in ethene.

Bioaugmentation



- Initially, the *Dehalococcoides* (DHC) population was low (10^2 cells/bead) and daughter products had accumulated suggesting MNA would not provide complete reductive dechlorination of PCE.
- Following bioaugmentation, the DHC population increased by 3 orders of magnitude with a corresponding decrease in DCE.
- Vinyl chloride (VC) concentrations temporarily increased due to the reductive dechlorination of DCE.
- The continued detection of DHC, however, indicated the potential for complete reductive dechlorination.
- VC concentrations decreased with a corresponding increase in ethene production.

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Microbial Insights

Environmental Remediation

Molecular Biological Tools

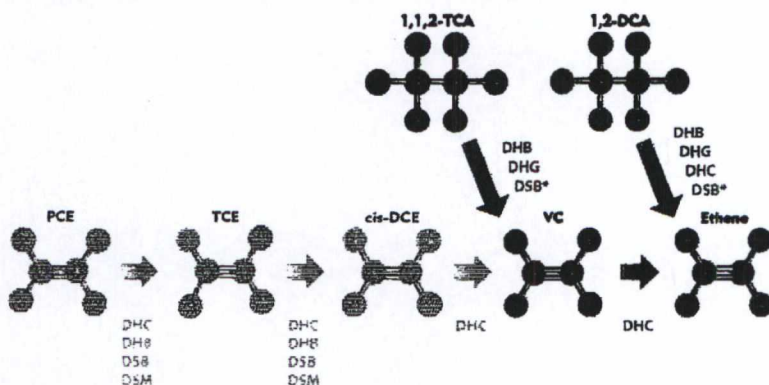
CENSUS - Chlorinated Ethanes

Chlorinated ethanes including trichloroethane (TCA) and dichloroethane (DCA) isomers were widely used as solvents, metal degreasers, and chemical intermediates in industrial processes and now are common groundwater contaminants. With potential adverse health effects including increased cancer risk, drinking water maximum contaminant levels (MCLs) have been established for 1,1,1-TCA, 1,1,2-TCA, and 1,2-DCA. In addition, chlorinated ethanes are also common co-contaminants at tetrachloroethene (PCE) and trichloroethene (TCE) impacted sites due to their similar commercial applications. The presence of 1,1,1-TCA can be especially problematic at PCE/TCE sites due to inhibition of reductive dechlorination chlorinated ethenes, particularly vinyl chloride.

CENSUS Targets for Reductive Dechlorination

Under anaerobic conditions, chlorinated ethanes are susceptible to reductive dechlorination by several groups of halo-respiring bacteria including *Dehalobacter*, *Dehalogenimonas*, *Dehalococcoides*, and *Desulfotobacterium* spp. While the reported range of chlorinated ethanes utilized varies by genus, species, and sometimes at the strain level, several general observations can be made regarding biodegradation pathways and daughter product formation.

- *Dehalobacter* spp. have been isolated that are capable of sequential reductive dechlorination of 1,1,1-TCA through 1,1-DCA to chloroethane.
- Biodegradation of 1,1,2-TCA by several halo-respiring bacteria proceeds via dichloroelimination producing vinyl chloride.
- Similarly, 1,2-DCA biodegradation often occurs via dichloroelimination producing ethene.



The following table describes the individual CENSUS targets and their importance in evaluating reductive dechlorination as a treatment mechanism.

Target	MI Code	Relevance / Data Interpretation
<i>Dehalobacter</i>	qDHB	<i>Dehalobacter</i> spp. have been implicated in the biodegradation of chlorinated ethanes ranging from tetrachloroethanes (TeCA) to dichloroethanes (DCA) and are therefore particularly important in assessing the potential for reductive dechlorination of chlorinated ethanes. <i>Dehalobacter</i> sp. and <i>Dehalobacter</i> -containing cultures have been shown to be responsible for sequential reductive dechlorination of 1,1,1-TCA through 1,1-DCA to chloroethane. Moreover, <i>Dehalobacter</i> spp. mediate the dichloroelimination of 1,1,2-TCA and 1,2-DCA to vinyl chloride and ethene, respectively.
<i>Dehalogenimonas</i>	qDHG	<i>Dehalogenimonas</i> spp. are a relatively recently described bacterial genus of the phylum Chloroflexi that are probably best known for reductive dechlorination of chloropropanes (1,2,3-TCP and 1,2-DCP). However, <i>Dehalogenimonas</i> isolates utilize several important

chlorinated ethanes including 1,1,2-TCA and 1,2-DCA as growth supporting electron acceptors.

<i>Dehalococcoides</i>	qDHC	Perhaps the most important reason to perform CENSUS® quantification of <i>Dehalococcoides</i> when evaluating a site impacted by chlorinated ethanes is to assess the potential for the reductive dechlorination of vinyl chloride produced by biodegradation of 1,1,2-TCA by <i>Dehalobacter</i> and <i>Dehalogenimonas</i> spp. In addition however, several <i>Dehalococcoides</i> spp. are capable of reductive dechlorination of 1,2-DCA via dichloroelimination.
<i>Desulfotobacterium</i>	qDSB	The range of electron acceptors utilized varies considerably between <i>Desulfotobacterium</i> isolates. For example, <i>Desulfotobacterium</i> dichloroeliminans strain DCA1 is capable of utilizing 1,1,2-TCA and 1,2-DCA as well as vicinal dichloropropanes and -butanes as growth supporting electron acceptors. Conversely, <i>Desulfotobacterium hafniense</i> Y51 cannot utilize or even transform TCA and DCA. Finally, <i>Desulfotobacterium</i> spp., unlike the organisms described above, are not obligate halo-respiring bacteria.
Methanogens	qMGN	Methanogens utilize hydrogen and carbon dioxide to produce methane. While common in the anaerobic environments conducive to reductive dechlorination, methanogens can compete with dechlorinating bacteria for available hydrogen. However, cometabolic dechlorination of 1,2-DCA by methanogens has also been reported.
Sulfate Reducing Bacteria	qAPS	The assay targets a gene involved in sulfate reduction. As with methanogens, SRBs can compete with dechlorinating bacteria for available hydrogen.
Total Bacteria	qEBAC	Quantification of total bacterial biomass.

CENSUS Targets for Cometabolism

While 1,2-DCA can be utilized as a growth supporting substrate, biodegradation of chlorinated ethanes under aerobic conditions is generally through cometabolism. The cometabolism or co-oxidation of chlorinated ethanes is mediated by monooxygenase enzymes with "relaxed" specificity that oxidize a primary (growth supporting) substrate and co-oxidize the chlorinated compound. To date, co-oxidation of chlorinated ethanes has been observed with a wide variety of primary substrates including methane, ethane, propane, butane, and ammonia.

The following table describes the individual CENSUS targets, their importance in evaluating cometabolism as a treatment mechanism.

Target	MI Code	Relevance / Data Interpretation
Soluble Methane Monooxygenase	qsMMO	Targets the soluble methane monooxygenase gene encoding the enzyme generally believed to support faster rates of cometabolism of TCE and co-oxidation of TCA and DCA isomers.
Propane Monooxygenase	qPPO	Propane can be added as a primary substrate to promote growth of propane utilizing bacteria capable of cometabolism of TCE and chlorinated ethanes including 1,1,2-TCA.

Butane Monooxygenase

qBOM

Like propane, butane can be added as a primary substrate to support cometabolism of chlorinated ethenes and chlorinated ethanes including 1,1,1-TCA.

Total Bacteria

qEBAC

Quantification of total bacterial biomass.

CENSUS[Overview](#)[How it works](#)[Applications](#)[■ Chlorinated Ethenes](#)[■ Chlorinated Ethanes](#)[■ Aerobic BTEX and MTBE](#)[■ Anaerobic BTEX](#)[■ Diesel](#)[■ Pentachlorophenol](#)[■ Perchlorate](#)[■ Wastewater treatment](#)[■ Bacterial groups](#)[Sampling](#)[FAQs](#)[Back to Services](#)[Select Language](#)**Contact Us**

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SAMPLING INSTRUCTIONS

Storage:

It is important to minimize the amount of time that Bio-Trap Samplers are stored prior to being installed in the field. The physical properties of the Bio-Trap Samplers that make them an ideal medium for collecting microbes also increase the chances of microbial or chemical contamination. Bio-Trap Samplers need to remain sealed and refrigerated (not frozen) until they can be installed in the field.

Note: Clean latex gloves (or similar) should be used at all times when handling Bio-Trap Samplers.

Installation:

- Prior to installing the Bio-Trap Sampler, the monitoring well may need to be purged if it has not been sampled in a while. If purging is necessary, MI recommends that three well volumes be removed to ensure contact with formation water and reduce well bore effect.
- Attach the Bio-Trap Sampler's nylon loop (provided) to a nylon line (not provided) and suspend the Bio-Trap Sampler at a depth where significant contaminant concentrations exist. If no data is available on the vertical distribution of contaminants, then suspend the Bio-Trap Sampler in the middle of the saturated screened interval.
- If large fluctuations in the water level are anticipated during the period of incubation, the Bio-Trap Sampler should be suspended from a float (contact MI for further details). Be sure not to suspend the Bio-Trap in the NAPL zone.
- Once installed, incubation times can vary depending upon the scope of the project (routine monitoring and stable isotope probing (SIP) - 30 days and "baited" - 60 days).

Retrieval:

- Open the monitoring well and pull up the Bio-Trap Sampler. Cut and remove the braided nylon line used to suspend the Bio-Trap Sampler.
- Transfer the recovered Bio-Trap Sampler to labeled (well number and date) zippered bags, seal and then double bag in a larger (one-gallon) zippered bag, immediately place on blue ice in a cooler.
- Repeat the above for all Bio-Trap Samplers from the site. Individual zippered bags containing the Bio-Trap Samplers can be placed in the same one-gallon zippered bag (if there is enough space).
- A chain of custody (COC) form must be included with each shipment of samples.
Hold time for this analysis is 24-48 hours.

SHIPPING INSTRUCTIONS

Packaging Samples:

1. Samples should be shipped in a cooler with ice or blue ice for next day delivery. If regular ice is used, the ice should be double bagged.
2. A chain of custody form must be included with each shipment of samples. Access our chain of custody at www.microbe.com.

Shipment for Weekday Delivery:

Samples for weekday delivery should be shipped to:

Sample Custodian
Microbial Insights, Inc.
2340 Stock Creek Blvd.
Rockford, TN 37853-3044
(865) 573-8188

Shipment for Saturday Delivery:

Coolers to be delivered on Saturday must be sent to our FedEx Drop Location. To ensure proper handling the following steps must be taken:

1. FedEx shipping label should be marked under (6) Special Handling, check Hold Saturday.
2. The cooler must be taped with FedEx SATURDAY tape.
3. The shipping label must be filled out with the Drop Location address below. Our laboratory name must be on the address label.
4. You **MUST notify by email** customerservice@microbe.com with the **tracking number** of the package on Friday (prior to 4pm Eastern Time) to arrange for Saturday pickup. Please make sure you write "Saturday Delivery" in the subject line of the message. **Without proper labeling and the tracking number, there is no guarantee that the samples will be collected.**

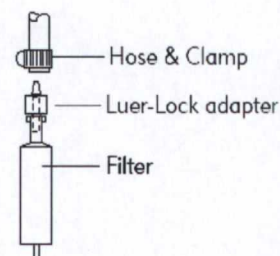
Samples for Saturday delivery should be shipped to:

Microbial Insights, Inc.
FedEx Drop Location
10601 Murdock Road
Knoxville, TN 37932
(865) 617-4782

Note: Samples received for Saturday Delivery will be frozen immediately upon receipt by Microbial Insights staff to minimize changes in the microbial community.

SAMPLING INSTRUCTIONS

1. Purge the well.
2. Prepare the pump (Peristaltic preferred, Grundfos, or air bladder) as normal. Use the clamp provided to ensure a leak-proof connection.
3. Remove the filter from the Falcon tube.
4. Attach the inlet of the filter with a 1/4" - 5/16" inner diameter (I.D.) tubing using the clamp to secure.
5. Place the filter within a receiving container so that the amount of water filtered can be measured accurately.
6. The amount of water filtered will vary depending upon the turbidity of the water. We recommend filtering 1-2 L.
7. Record the volume of water that passed through the filter, and then submit the filter for analysis. The water may then be discarded. Please cap the filter on both ends. The thinner end should be closed with the red rubber cap and the thicker end should be closed with the clear luer plug.



Note: If the filter clogs before 1L has been filtered, record how much water was passed through the first filter, and then collect an additional filter, also recording the volume of water that went through the second filter. In this case, both filters are then submitted for testing. For each location there should be **no more than 2 filters** used and there is no need to filter more than 2L of water.

Hold time for this analysis is 24-48 hours.

To Submit Sample:

1. Place the filter in the Falcon tube provided.
2. Affix the label to the Falcon tube and note the amount of water that passed through the filter, the well location, sampling date, and the analyses requested.

SHIPPING INSTRUCTIONS

Packaging Samples:

1. Samples should be shipped in a cooler with ice or blue ice for next day delivery. If regular ice is used, the ice should be double bagged.
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2. The cooler must be taped with FedEx SATURDAY tape.
3. The shipping label must be filled out with the Drop Location address below. Our laboratory name must be on the address label.
4. You **MUST** call Microbial Insights, Inc. with the tracking number of the package on Friday (prior to 4pm Eastern Time) to arrange for Saturday pickup. **Without proper labeling and the tracking number, there is no guarantee that the samples will be collected**

Samples for Saturday delivery should be shipped to:

Microbial Insights, Inc.
FedEx Drop Location
10601 Murdock Road
Knoxville, TN 37932
(865) 617-4782 or (865) 384-4005

Note: Samples received for Saturday Delivery will be frozen immediately upon receipt by Microbial Insights staff to minimize changes in the microbial community.

SAMPLING INSTRUCTIONS

The following sampling instructions are used for collecting water or groundwater samples for DNA analysis by DGGE and/or CENSUS. The recommended sampling container is a 1L Poly bottle with a screw cap. Amber glass bottles can be used but are not recommended due to the likelihood of breakage during shipment. Microbial Insights, Inc. can provide the proper sampling supplies upon request.

Once the proper sampling bottle is obtained be sure not to contaminate the inside of the sample bottle with skin, dirt or any form of debris (this helps to ensure the accuracy of the data results). Wearing latex gloves (or similar) is recommended when sampling.

The required volume of water to conduct DNA based analyses from groundwater samples is 1L.

* Note: It is important to collect as close to the required amounts as possible to ensure the ability to properly conduct the analysis requested.
Hold time is 24-48 hours for this analysis.

To Submit Sample:

1. Once the required amount of groundwater has been collected into the proper sampling container, seal the container tightly with a screw cap lid.
2. Properly affix a label with the sample name, date and analysis.
3. Be sure to fill out the Chain of Custody (COC) form correctly and accurately and ship it along with the samples. A COC form is required for QA/QC purposes.
4. Once the bottles have been correctly labeled, place them in the designated cooler. Be sure to fill the remaining space in the cooler with blue ice or regular ice that has been double bagged in Ziploc bags. Use sufficient ice to keep the entire shipment around 4°C, especially during the summer months.
5. All paperwork to be sent with the samples should be placed within a waterproof pouch or Ziploc bag and placed on top of the samples or affixed to the inside lid of the cooler.
6. Seal the cooler lid with a strong packaging tape.

SHIPPING INSTRUCTIONS

Packaging Samples:

1. Samples should be shipped in a cooler with ice or blue ice for next day delivery. If regular ice is used, the ice should be double bagged.
2. A chain of custody form must be included with each shipment of samples. Access our chain of custody at www.microbe.com.

Shipment for Weekday Delivery:

Samples for weekday delivery should be shipped to:

Sample Custodian
Microbial Insights, Inc.
2340 Stock Creek Blvd.
Rockford, TN 37853-3044
(865) 573-8188

Shipment for Saturday Delivery:

Coolers to be delivered on Saturday must be sent to our **FedEx Drop Location**. To ensure proper handling the following steps must be taken:

1. FedEx shipping label should be marked under (6) Special Handling, check Hold Saturday,
2. The cooler must be taped with FedEx SATURDAY tape.
3. The shipping label must be filled out with the Drop Location address below. Our laboratory name must be on the address label.
4. You **MUST** call Microbial Insights, Inc. with the tracking number of the package on Friday (prior to 4pm Eastern Time) to arrange for Saturday pickup. **Without proper labeling and the tracking number, there is no guarantee that the samples will be collected.**

Samples for Saturday delivery should be shipped to:

Microbial Insights, Inc.
FedEx Drop Location
10601 Murdock Road
Knoxville, TN 37932
(865) 617-4782 or (865) 384-4005

Note: Groundwater samples received on Saturday cannot be frozen and therefore may exceed recommended hold times.

Appendix C

Manufacturers Information on Field Equipment
